ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. V OCTOBER–NOVEMBER, 1910 No. 7

STRUCTURE AND ORIGIN OF THE MAGNETITE DEPOSITS NEAR DILLSBURG, YORK COUNTY, PENNSYLVANIA.[1]

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INTRODUCTION.

Dillsburg is a small village on the Cumberland Valley Railroad about fifteen miles southwest of Harrisburg (see Fig. 60). It is situated just within the border of the Mesozoic belt southeast of South Mountain which here consists largely of Cambrian sandstone and quartzite. Northwest of South Mountain is the Appalachian Valley underlain by Cambrian limestone, shale and sandstone.

The Mesozoic belt trending northeast-southwest has a width of about eighteen miles at this point, extending southeastward from Dillsburg almost to York. The rocks composing it are red sandstones and shales intruded by large masses of diabase. Near the intrusions the sandstones are baked and discolored. The Mesozoic sediments lie on a basement of Paleozoic or older rocks. Wherever they lie on limestone the basal part of the series contain numerous layers of limestone conglomerate and interbedded calcareous layers.

The iron ores of the Dillsburg district are of two types—magnetite deposits scattered through an area about one mile square, the center of which is about one and one half miles east of Dills-

[1] Published with the permission of the director of the U. S. Geological Survey.

burg, and brown ore deposits on the slope of South Mountain north of Dogwood Creek from two miles to three miles west of Dillsburg. The magnetite deposits are of the Cornwall type occurring in Mesozoic sediments near the contact with intrusive diabase, while the brown ores are found in variegated clays associated with Lower Cambrian (Antietam) sandstone. One brown

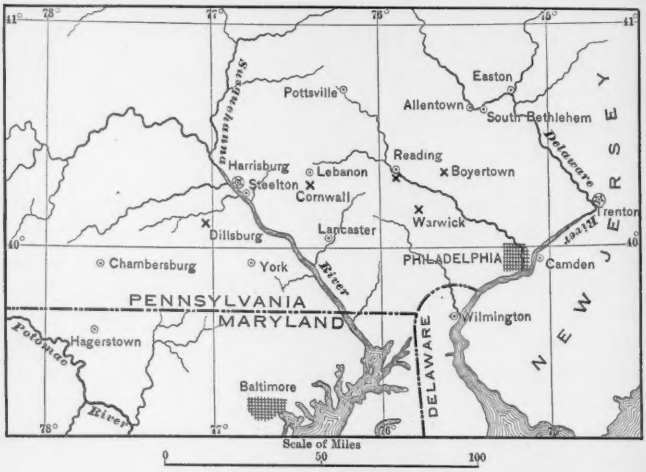

FIG. 60. Map showing the location of the principal contact magnetite deposits in southeastern Pennsylvania.

ore mine, the Heck mine, two and one half miles west of Dillsburg, is at present producing ore, and stripping has recently been done on the Pinkerton tract bordering the Heck mine on the northeast. Ore has also been mined in recent years at the Jauss magnetite mine, one and one half miles east of Dillsburg, but at present no magnetite is being mined in the district. Prospecting is being done on the McClure and Smyser tracts, however.

DISTRIBUTION AND CHARACTER OF THE ROCKS.

The contact between the Paleozoic sediments of South Mountain and the Mesozoic rocks to the southeast trends northeast-

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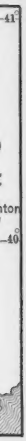

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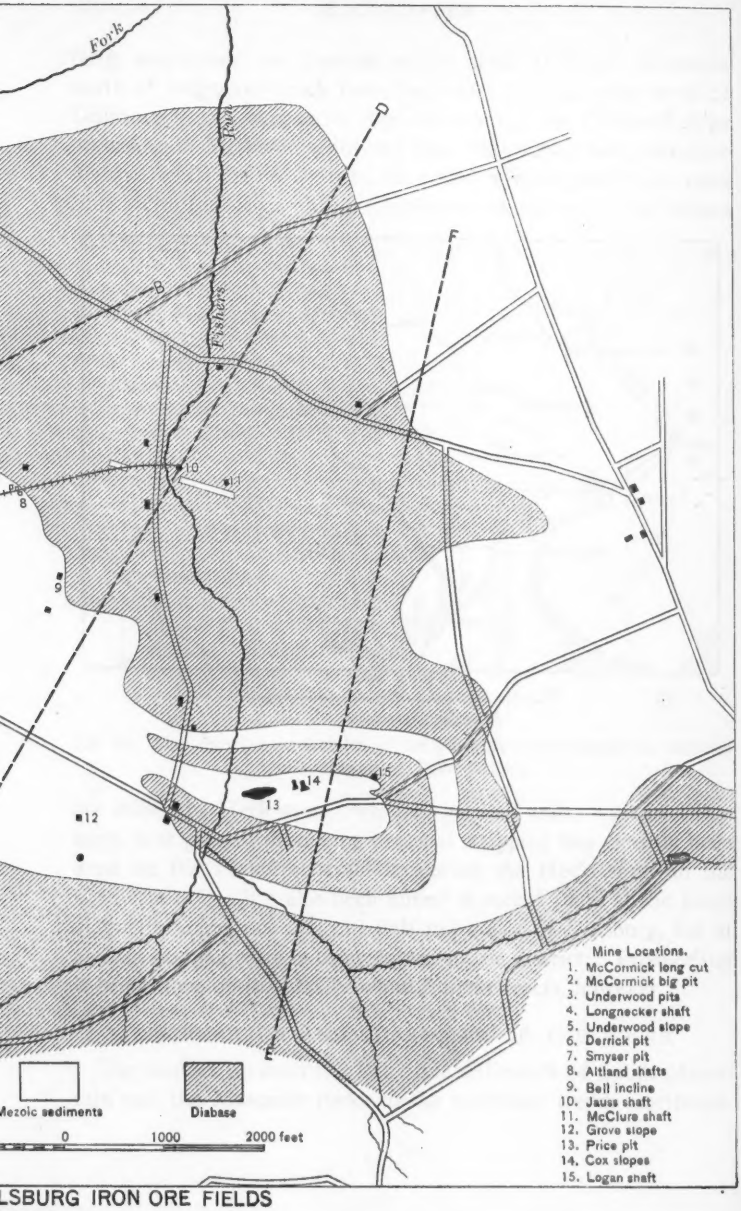
PLATE VIII

GEOLOGIC MAP OF DILLSBURG IRON ORE FIE

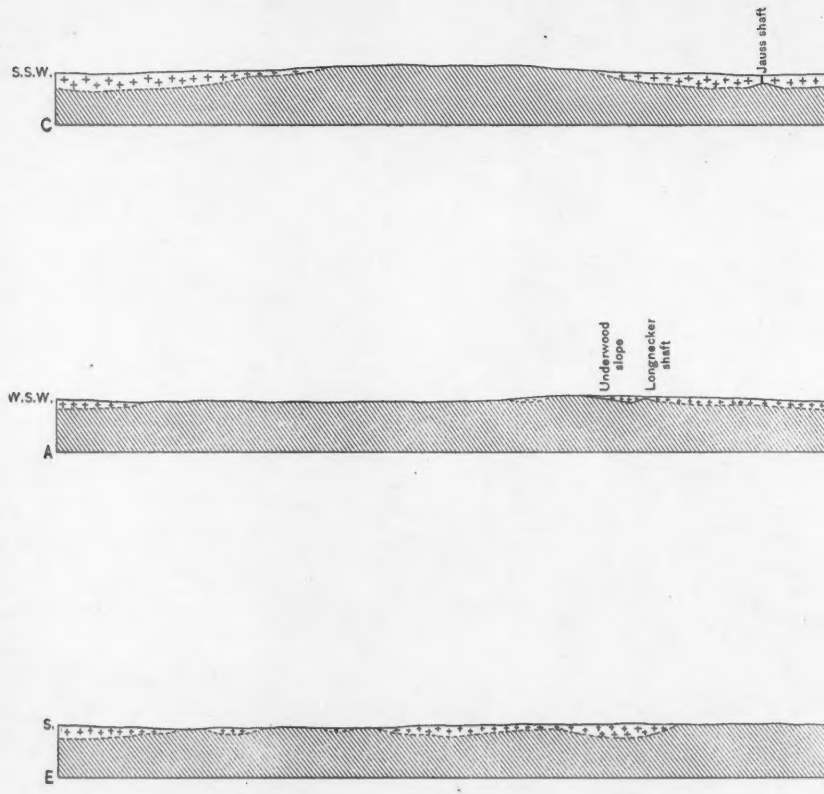
Modified from Spencer.



LSBURG IRON ORE FIELDS

from Spencer.

PLATE IX



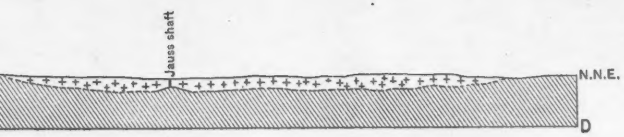
Mesozoic sediments

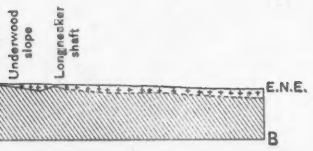
Diabase

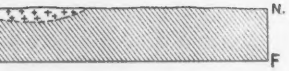
Probable contacts

GEOLOGIC SECTIONS OF DILLSBURG MAGNETITE A

(Same scale as map)







DILLSBURG MAGNETITE AREA

scale as map)

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southwest, passing about one mile northwest of Dillsburg. The northwestern part of the town of Dillsburg is underlain by Mesozoic sediments, largely limestone conglomerate, while the southeastern part is underlain by diabase which is part of a belt that comes in from the southeast but here turns and runs southwestward. To the southwest it becomes narrow but to the southeast it widens and eventually runs into a large diabase area three or four miles in width. East of Dillsburg north of this diabase belt is a low meadow underlain by sediments while east of this and also north of the diabase belt is the large diabase area with which most of the magnetite deposits are associated (see Pl. VIII.). In the sediments on its west border and in the strip of sediments between it and the diabase belt to the south there are smaller diabase outliers. Another diabase belt occurs north of Dillsburg and connects with a large diabase area to the northwest in the region south of Grantham.

The main diabase mass with which the ores are associated apparently lies on the sediments with a rolling uneven contact, while the outlying small masses appear to be erosion remnants lying in troughs on the surface of the sediments. The sediments underneath the diabase mass are continuous with those surrounding them and have the same prevailing dip, which is between 10° and 30° to the north (see Fig. 61).

The prevailing formation in the Mesozoic sediments around Dillsburg, according to Spencer, is limestone conglomerate. The rock is exposed at several quarries west and northwest of the town and was encountered in many of the walls and cellars in Dillsburg. Thicknesses as great as 50 and 80 feet have been reported. Locally it was found interbedded with red shale and sandstone. The limestone conglomerate consists largely of pebbles of blue, pink and white limestone with a fine calcareous matrix.

In the iron ore area the rocks are largely fine-grained sandstones with interbedded limestone layers. They have been metamorphosed and their prevailing color is yellow or brown at the surface and light grayish green underground. A pebbly structure is apparent in many of the limestones, but in others it has

been obliterated. It is probable that many of the latter were not conglomeratic originally but simply limestones or calcareous sandstones. Most of them contain considerable sandy and clayey material. The sandstones occur interbedded with the calcareous layers. They are dense and fine-grained and locally slaty.

The diabase is usually medium-grained, but near the contact with the sediments it becomes dense and fine-grained.

The magnetite deposits occur in the sediments under the diabase and close to the border of the diabase in sediments that were formerly covered by it. They are in the form of layers interbedded with layers of barren shale and sandstone, and are probably replacements of original calcareous beds. The shale and sandstone layers have been baked and metamorphosed but no ore is developed in them.

DESCRIPTIONS OF THE MINES.

The principal magnetite mines are all located on the west and south border and within the main diabase area east and southeast of Dillsburg. They occur along a northwest-southeast zone about one and one half miles long and from one fourth to one half mile wide.

The chief mines and prospects which are near the border of the diabase area or just within it are from northwest to southeast (see Pl. VIII.)—McCormick long cut, McCormick big pit, Underwood pits, Longnecker shaft (formerly Logan mine), Underwood slope, Derrick pit, Smyser pit, Altland shafts, Bell incline, Grove slope, Price pit, Cox slopes and Logan shaft. The Jauss and McClure shafts are within the diabase area at some distance from the border. Most of these mines were described in reports of the Pennsylvania Geological Survey[1] many years ago, while they were still in operation. More recently they have

[1] Frazer, Persifor, Jr., "Report of Progress in the Counties of York, Adams, Cumberland, and Franklin, 1875," Second Geol. Surv. of Pa., 1875, Rept. CC, pp. 207–239. "Report of Progress in the Districts of York and Adams Counties, 1874," Second Geol. Surv. of Pa., 1874, Rept. C, pp. 71–76.
D'Invilliers, E. A., "Report on the Iron Ore Mines and Limestone Quarries of the Cumberland-Lebanon Valley," 1886. Pa. Geol. Survey Ann. Rept., 1886, Pt. IV., pp. 1501–1513.

been described by Spencer,[1] who summarizes the descriptions contained in the Pennsylvania reports and gives further information concerning the geology and structure of the ores gained by a study of surface outcrops. Mr. Spencer was not able to go underground at the time of his examination, because the mines were full of water, and it was in order to see the underground workings of the Jauss mine, which was recently unwatered, that he and the writer visited the district this spring.

The first mines were opened before 1850 and from that time to the present new mines have been opened from time to time, worked intermittently and finally abandoned. The first mines opened were the open cuts on the Underwood, McCormick and Smyser tracts and on the Price property. Nearly all the open pit workings, however, were abandoned before 1875. About that time the Underwood deep mines, the Longnecker shaft, the McClure shaft, the Bell mine, and probably the Jauss mine were opened. The last opening made in the district with the exception of recent explorations was the Logan mine. The Underwood deep mines have been abandoned since 1887; the other mines also were abandoned one after another, except the Bell slope, which was operated until 1902. The Jauss mine was reopened in recent years and has produced small quantities of ore intermittently. At present drilling is being conducted on the Smyser tract, while a shaft and several drill holes have recently been sunk on the McClure tract. The following are brief descriptions of the mines based partly on personal observation and partly on descriptions from the earlier geological reports to which the reader is referred for more detailed information.

The McCormick long cut is in the sedimentary area, at some distance from the main diabase contact. The diabase, however, probably extended over this area at no great distance above the present surface. The cut runs a little north of east, nearly parallel to the strike of the rocks apparently extending along a single ore horizon between sandstone beds. On the north wall is

[1] Spencer, A. C., "Magnetite Deposits of the Cornwall Type in Pennsylvania," Bull. U. S. Geol. Survey, No. 359, pp. 74–96. "The Jauss Iron Mine, Dillsburg, Pennsylvania," Bull. U. S. Geol. Survey, No. 430 E, pp. 31–33.

a heavy bed of baked barren sandstone with disseminated garnet, while on the south wall baked sandstone also is exposed in a few places. The dip of the bedding of the sandstones at the surface is about 20° to the north. Near the middle of the cut are the remains of a slope, known as the "Rock slope," which ran northward down the dip of the bedding, presumably folllowing the ore bed between the barren sandstone layers.

Several drill holes, ranging in depth from 50 to 115 feet have been sunk in the vicinity of the long cut and in them trap is reported at varying depths. Since, however, the term dolerite or trap is applied also in the early reports to the baked sandstone which forms the hanging wall of the ore, it is more than likely that the material in the drill holes is baked sandstone.

The McCormick long cut is the northernmost of the larger workings, and therefore this ore bed is the uppermost productive ore bed mined in the district. As the strike and dip of the sediments is fairly regular throughout the district, it is plain that the mines to the south have worked ore bodies which are successively lower stratigraphically. The ore horizons on which the southernmost mines are located, namely the Grove, Cox, Price and Logan, are about 5,000 feet south of the McCormick long cut. Assuming that they have an average dip of 20° to the north, this would bring them about 2,700 feet stratigraphically and 3,000 feet vertically below the ore horizon of the McCormick long cut. Under similar conditions the ore horizon of the Bell mine 3,000 feet south would be about 1,600 feet below the McCormick bed stratigraphically and 1,800 feet vertically.

However, the chances that these beds are ore bearing below the McCormick long cut are very slight, because of their distance beneath the diabase mass. It is supposed that the solutions which have formed the ore have come out of the diabase and have replaced the calcareous beds for varying distances from the contact. Even under exceptional conditions this metamorphism can not be supposed to have extended 1,500 or 2,000 feet from the contact. Other diabase masses might have been intruded underneath the mass now exposed and have formed ore at their contacts, but such a supposition is purely hypothetical.

On the other hand, it is possible that these lower horizons are altogether absent underneath the area of the McCormick long cut. If the sediments were deposited close to a shore, the land area being presumably to the north, then successively higher strata would overlap those below and the lower strata would pinch out on going northward. In this case the strata carrying ore at the southernmost mines might be absent underneath the McCormick workings, the Paleozoic basement occupying their place. Such a structure, however, would necessitate an abnormally steeply southward sloping bank for the basin in which the sediments were laid down and it seems more probable therefore that the Paleozoic basement is a considerable distance below the surface.

The McCormick big pit is in sediments but touches the big diabase mass at its eastern end. On its western wall there are baked sandstone exposures. From the trend of the pit and the position of the exposures it appears that the ore bed had a strike a little north of east and dipped to the north. A shaft was sunk in the bottom of the pit to a depth of 140 feet and a drill hole to a depth of 188 feet. The principal rocks: encountered in the latter were green and white sandstones. Thin ore beds were found at several horizons in the upper part but no diabase. This among other evidences shows that the diabase mass to the east does not dip under the sediments but lies on them. It probably overlay the area of the big pit at but a very short distance above the present surface. In the lower part of the drill hole limestone and red sandstone were encountered.

About 100 feet north of the pit a slope was put down 10 feet on a bed of ore which was 4 feet thick at the bottom. It is possible that other ore beds occur between this and the McCormick long cut. Several other smaller pits occur east of the big pit.

The Underwood workings include the Underwood pits, the Underwood slope and the Derrick pit and shaft, besides several unnamed pits and shafts (see Fig. 61). The Underwood slope is in the diabase area and masses of diabase are exposed at its mouth. It sinks to the north at an angle of 28° and is about

500 feet long, having drifts running east and west from it at three levels. The diabase was penetrated and ore encountered at a depth of 26 feet. The ore is said to dip to the north and to have a hanging wall of diabase and a foot wall of sandstone intermixed with limestone. Where the slope enters the ore it is said to have had a thickness of 18 feet. Down the dip the ore bed

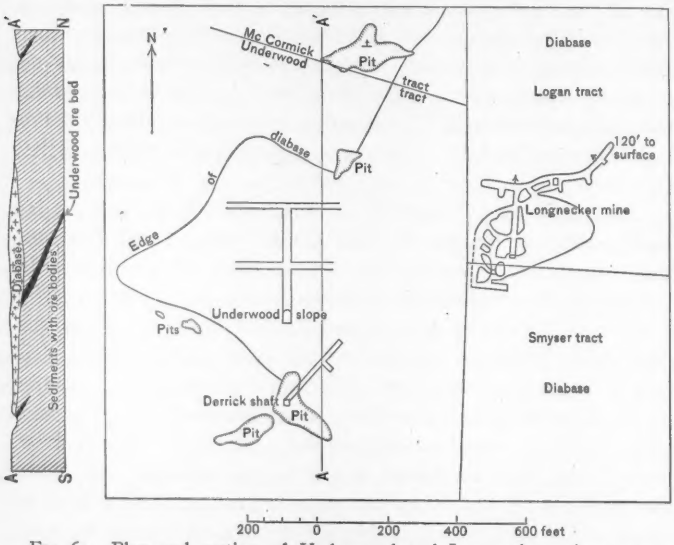

FIG. 61. Plan and section of Underwood and Longnecker mines near Dillsburg. (Modified from Spencer.)

soon divided into two beds, an upper and a lower, separated by slaty sandstone.

A 96-foot shaft was sunk some distance east of the slopes and the following section was passed through:

38 feet of diabase.
7 to 8 feet of lean ore.
14 feet of sandstone.
8 feet of good ore.
26 feet of sandstone.
15 to 20 feet of ore.
white calcareous sandstone.

A third shaft, formerly known as the Longnecker, was sunk to a depth of 95 feet east of the 96-foot shaft and just west of the point where the Logan, Underwood and Smyser tracts come together. From its bottom a slope extends northward up to the line of the McCormick tract, a distance of 400 or 450 feet. Several drifts were run east and west from this slope. The ore is said to have been 20 or 30 feet thick in places. The lower 20 feet of the shaft are in ore; the upper part is in diabase.

Pits occur abundantly on the Underwood tract all along the border of the diabase area from the McCormick workings to the Smyser pit, but all except five or six of them are small.

The northernmost of the important pits is on the contact of the diabase and the sedimentary area south of the McCormick big pit and north of the Underwood slope. Baked sandstone is exposed on the north and west walls and diabase boulders occur in the soil on the south wall. The ore bed mined here evidently dipped northerly under the sandstone. The diabase contact probably dips southward at a small angle so as to strike the Underwood slope 26 feet below the surface and the shaft west of it 38 feet below the surface.

A large pit overgrown with brush and trees and a shaft occur in the sedimentary area northwest of the Underwood slope. No rock is exposed in this pit, but between it and the Underwood slope there are numerous small pits which struck diabase.

The Derrick pit is on the diabase contact several hundred feet south of the Underwood slope and just west of it is another large pit. Both pits are overgrown with brush and trees and no rock exposures occur. The soil is red and contains numerous fragments of iron ore. A shaft was sunk in the Derrick pit and is said to have penetrated 25 feet of diabase and 28 feet of ore. The ore bed was worked 250 feet or more north from the shaft.

Southeast of the Derrick pit are two small pits which extend a little north or east from an outlying diabase area to the main diabase area, evidently following a single ore horizon.

The Longnecker mine is east of the Underwood deep mines, farther within the main diabase area. It consists of a vertical shaft 51 feet deep, the upper 27 feet of which are in diabase.

The ore bed is said to have been 20 feet thick at the shaft and to have averaged 10 feet thick in the mine. A slope was sunk northward from the bottom of the shaft along the ore bed at an angle of 28° for a distance of 215 feet and then a drift was run northeasterly for a distance of 249 feet. The end of this drift is about 120 feet below the surface. In the deeper workings the dip of the ore bed is shallower than at the shaft. It is reported that the hanging wall of the ore bed is diabase, but this is not an assured fact since baked sandstone beds were frequently taken for diabase by the early geologist and miners. Limestone conglomerate was also encountered. The ore has been worked out for a considerable distance on both sides of the main slope.

The lower surface of the diabase is very irregular between the Longnecker shaft and the Underwood deep mines, varying greatly in its depth beneath the surface. At one point it is said to be 90 feet in depth and within a short distance of it only 15 feet.

The Smyser pit is just north of the grade of the old branch railroad which ran from Dillsburg to the iron mines, and is east of the road which runs past the Longnecker mine and the Underwood and McCormick workings. Diabase is said to have been associated with the ore but at present no exposures can be seen in the vicinity of the pit. A drill hole, however, is being sunk less than one hundred feet northwesterly from the pit which at the time of the writer's visit was 23 feet deep and entirely in diabase.

The Altland mine consists of several shafts near the railroad grade where the siding from the Bell mine joins the main branch. The main shaft is 62 feet deep, ore being struck at 57 feet. From the bottom a slope runs northward on the ore bed which dips 23° and has a thickness ranging from 4 to 7 feet. The slope is 125 feet long and near the lower end drifts were run east and west from it. The hanging wall of the ore bed is said to have been trap in the upper part of the slope, but in the lower part a bed of indurated slate rock wedged in between the ore and the trap. The ore bed was worked at the surface south of the railroad. The contact of the main diabase area, according to Spencer, is just northeast of the mine.

The Bell mine is about 1,000 feet east of south from the Altland mine and just west of the main diabase mass. It consists of an incline which runs N. 10° E. underneath the edge of the diabase and is said to have a dip of 20°. It was over a thousand feet long and followed an ore shoot which is said to have had a maximum width east and west of 60 feet and was 10 or 12 feet thick at a point 875 feet down the slope. It was cut off on the east by the diabase which crosscuts the sedimentary strata (see Fig. 62). On the west it graded into the sediments. Appar-

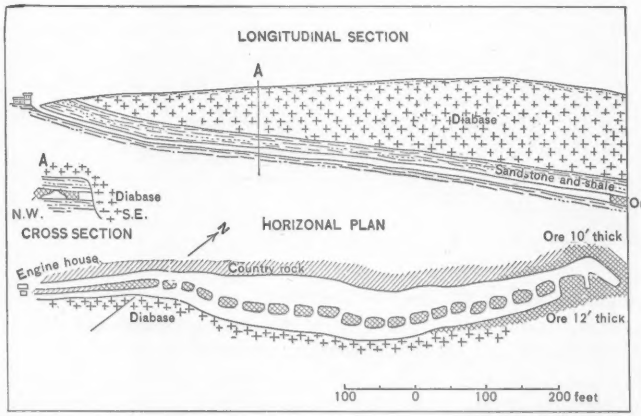

FIG. 62. Plan and sections of Bell mine, near Dillsburg. (After Spencer.)

ently this northward-dipping ore shoot is in the contact zone along the easterly dipping edge of the diabase mass, the ore replacement having taken place at a maximum width of 60 feet from the diabase. Baked sandstone occurs at the mouth of the slope, while to the east are a number of small old pits from which diabase has been taken.

The Jauss mine is situated just east of Fisher's Run at the end of the branch railroad from Dillsburg. It is a little south of the center of the big diabase area and no sediments occur at the surface near it. The mine consists of a shaft 72 feet deep which just penetrates the diabase, striking sediments and ore under-

neath (see Fig. 63). At the bottom is an incline 270 feet long dipping 17° N. 30° W. The end of the incline is about 145 feet below the surface. The dip of the sediments is north-northeast, the incline running down an ore bed at an angle between the strike and the dip. The general dip of the sediments is therefore somewhat steeper than the dip of the incline, in places being as much as 35°. At the bottom of the incline, however, the dip becomes very shallow, being only about 12°.

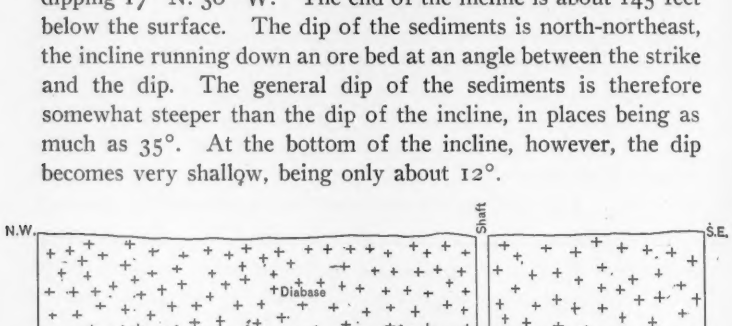

FIG. 63. Section at Jauss Mine, near Dillsburg, in direction of incline, showing structure of ore bodies.

There are three ore beds in the mine, the middle one of which is followed by the incline. This bed has been worked out on both sides of the incline for a varying distance wherever it was rich enough to work. The upper ore bed has been worked at several places in the mine and locally considerable chambers have been opened on it. It is 5 feet thick and is separated from the middle bed by a parting of baked shaly sandstone 3 feet thick. The middle ore bed has an average thickness of 7 or 8 feet. The third ore bed lies underneath the incline and has only been exposed by drilling. It is said to have a thickness of 7 feet and is separated by 5 feet of baked sandstone from the middle bed. It is possible that other ore beds exist underneath it.

The diabase apparently overlies the sediments with an irregular contact. At the bottom of the shaft it dips steeply to the south

yet at several points along the slope it is said to be but a short distance above the ore beds.

The McClure or King mine is 750 feet south of east of the Jauss shaft. It consists of a shaft which passed through 23 feet of soil and diabase, beneath which were 9 feet of ore. Toward the east a 20-foot drift encountered diabase on the south wall. The ore bed is said to have a general dip of 22° N. 10° W., while the sediments at one place in the workings show a dip of 23° N. 40° W. Nothing remains now to show the location of the shaft except a dump consisting of sandstone and lean ore fragments. A number of pits were sunk in the vicinity of the shaft and in nearly all of them the diabase is said to have been penetrated at a depth varying from 10 to 30 feet and ore encountered beneath.

Recently drilling has been done here and a shaft sunk to a depth of about 15 or 20 feet, the diabase being apparently not penetrated.

The Grove slope is about 2,500 feet south of the Bell mine. It is in the sedimentary area with apparently no diabase near it, though diabase probably originally overlay the area. The dip of the rocks is given as 24° N. 10° E.

The Price pit is about 1,400 feet east of the Grove mine. Baked sandstone is exposed on the north wall, dipping in a northerly direction. North of it is a belt of diabase which continues eastward north of the Cox and Logan mines. North of the diabase, according to Spencer, is a sedimentary strip and beyond this the main diabase area.

The Cox mine consists of two old slopes now nearly obliterated. The soil is red like diabase soil and contains weathered magnetite fragments. The slopes were 280 and 300 feet long, respectively, dipping northward along an ore bed. The same ore bed was also encountered by a nearby shaft at a depth of 40 feet. It is said to have averaged 5½ to 6 feet in thickness, though in places reaching 9 feet. The footwall of the ore bed is said to have been formed by sandy limestone and the hanging wall by gray trap.

The Logan mine consists of a shaft just within the diabase belt

south of which the Cox and Price are located. Outcrops of diabase occur southeast of the mine, but the diabase was penetrated in the shaft at a depth of 32 feet, showing that the contact between it and the underlying sediments dips at a low angle to the north. Underneath the diabase the shaft is said to have encountered 7 feet of ore which had a floor of limestone conglomerate. Baked sandstone also was encountered as is shown by the material on the dump.

STRUCTURE OF THE ROCKS.

South Mountain extends northeastward from Franklin County along the boundary of Cumberland and Adams counties and ends on the northwest border of York County. It terminates abruptly northwest of Dillsburg, dropping off into the gently undulating valley region to the north and into the more rough Mesozoic region to the east and south, which consists of hills and ridges of trap with intervening valleys, largely underlain by sediments.

The northeastern end of South Mountain consists structurally of two parallel northeast-southwest trending anticlines, forming two prominent ridges between which is the synclinal valley of Dogwood Creek.

The summits of the ridges are composed of the Montalto quartzite, while the lower slopes consist of the overlying Antietam sandstone. About 25 miles to the southwest, in Franklin County, the Montalto quartzite becomes simply a member of the Harpers schist. In the valley of Dogwood Creek no exposures occur but it is thought to be underlain by Tomstown limestone, this being the normal Lower Cambrian succession.[1]

The Mesozoic sediments have been laid down upon a floor of these older rocks and have later suffered folding and tilting so that in the region around Dillsburg they now dip to the north at varying angles. The iron ore area is in direct line with the valley of Dogwood Creek and the Mesozoic sediments here are probably underlain by the Tomstown limestone.

The lower part of the Mesozoic sediments where underlain by

[1] Stose, G. W., unpublished notes.

older limestones consists largely of limestone conglomerate; these conglomerate beds in places occur for a considerable distance up in the series interbedded with shales and fine-grained sandstones. Calcareous layers, not noticeably conglomeratic, also occur abundantly. The entire series, as exposed in the iron ore area, is probably a shore phase of the massive red sandstones so characteristic of the Mesozoic belt elsewhere. It is believed by Spencer that, while the deposition was taking place, the basin gradually increased in size so that the higher beds overlap those below. The general structure and distribution of the shore phases seem to correspond with this supposition.

Diabase was intruded into the sediments after their deposition and consolidation. It probably came up through the older rocks along narrow fissures and, when it reached the overlying Mesozoic sediments, spread out into irregular intrusions sometimes breaking through along the bedding but in general cutting across the bedding irregularly.

The material in the original fissures in the older rocks cooled in the form of dikes, while that in Mesozoic sediments formed large irregular masses. Trap dikes are found in the Paleozoic rocks at several localities in the Appalachian valley north of the Mesozoic belt, notable among which is one that extends northward across the valley east of Carlisle for a distance of at least 25 miles, having an average width of 40 feet. Locally there may also have been large intrusions in the Paleozoic rocks besides the dikes.

The diabase mass east of Dillsburg, with which the magnetite is associated, lies with an irregular contact upon the upturned edges of the sediments, which dip to the north at angles varying between 10° and 30°. There are pronounced rolls in the diabase-sediment contact which locally brings the sediments quite close to the surface some distance within the diabase area. This is the case at the McClure and Jauss shafts and is probably also true of the area between them and the Longnecker shaft and beyond them to the east toward the marked sedimentary embayment. The small diabase areas around the borders of the main mass, which are described by Spencer as sills, are probably out-

liers which occupy minor troughs on the surface of the sediments and were formerly connected with the principal diabase mass.

It is not known whether the main diabase mass is directly connected underneath by dikes with the underground reservoir from which the magma was derived, but it is probable that such is not the case and that the vent through which it came up is some distance away, perhaps under the great diabase mass to the south.

There are several reasons for believing that the diabase magma came up through relatively small, though extensive, fissures in the older rocks and broke out into large irregular intrusions where it reached the softer Mesozoic sediments rather than that the large masses connect directly underneath by great vents with the underground reservoir. The principal reason for this belief is that no such large vents are now seen in the older rocks north or south of the Mesozoic belt, though thin dikes of great longitudinal extent occur at several points as cited. Most of the great diabase masses stop abruptly at the edge of the Mesozoic belt as though they lay on the older rocks, just as the associated sediments, rather than had broken through the older rocks.

If the large diabase masses east of Dillsburg were directly connected underneath with the original reservoir it does not seem possible that the structure of the sediments should be so little affected (see Plate IX.). These have the same regular strike and dip throughout the area, underneath the diabase mass as well as in areas away from it. Wherever the diabase mass has been penetrated sediments have been shown to occur underneath and there is no reason for believing that they would not be encountered with depth throughout the diabase area.

STRUCTURE AND ORIGIN OF THE ORES.

The ores occur in the sediments underneath the diabase or along the borders of the diabase area in sediments which were presumably recently covered by it. They are replacements along layers of limestone conglomerate or other calcareous layers interbedded with shales and fine-grained sandstones. Much unreplaced, partly altered rock and numerous metamorphic minerals are found along the ore layers while the sandstone partings be-

tween the successive ore beds are baked and metamorphosed with generally an abundant development of metamorphic minerals. The principal minerals in the ores besides magnetite are pyroxene, epidote, chlorite, calcite, feldspar, pyrite, sericite, quartz and garnet, those in the barren sandstone layers are largely garnet, quartz, pyroxene, and pyrite. The barren sandstone beds vary in thickness from two to three feet, as in the ore zone at the Jauss mine, to perhaps over a hundred feet, as may be the case between the ore horizon at the Altland shafts and Bell incline, or between the latter and ore horizon along which are located the Logan shaft and the Cox and Price workings. However, it is probable that undiscovered ore beds exist in these intervals.

The ore bodies are not always well defined beds, but may occur as irregular masses replacing those portions of the bed which were originally more calcareous. The replacement has taken place for varying distances from the diabase contact. In the Bell mine the maximum distance was apparently 60 feet, yet in many of the other mines the ore beds have been followed several hundred feet down the dip below the diabase.

The ore consists almost entirely of magnetite and is in general of low grade running about 45 to 50 per cent. metallic iron or even less. It is high in sulphur, due to the presence of pyrite and nearly all of it will require roasting before it can be marketed. The presence of gangue minerals and decomposed rock is the chief factor which tends toward lowering the grade of the ore. Many large masses consisting of half ore and half gangue material occur and if mechanical concentration could be made to pay there would be an immense tonnage of ore in sight in the district.

The magnetite for the most part is granular or finely crystalline, but locally geodes of medium coarse crystals occur. The ore is quite soft and most of it slacks on exposure to the weather because of the abundance of calcite in it. In some places pure ore containing only a little pyrite, chlorite, feldspar, or pyroxene occur, but for the most part the ore beds are made up of a mottled mixture of ore and gangue material, sometimes the one being predominant, sometimes the other. The original limestone or

limestone conglomerate beds seem to have been impure and to have varied in the amount of impurities present in different parts. Locally, where limestone conglomerate was apparently the original rock, the pebbles seem to have been replaced by ore and the matrix decomposed without much replacement. In the interbedded sandstone or slate layers between the ore beds there has been apparently no replacement by ore whatever.

From the nature of the ore and the association of metamorphic minerals it seems clear that the ores were deposited by hot, deep-seated solutions. The constant association of the deposits with the diabase contact and their absence in areas away from the diabase points to the latter as being directly or indirectly the source of these hot solutions. The ore solutions evidently came up from the same reservoir as the diabase magma, and this may have taken place in one of two ways. (1) They may have come up along the same vents through which the magma was forced, or (2) they may have come through fissures or along pervious zones elsewhere. The close association of the ore with diabase masses seems to point to these particular diabase masses as the controlling influences in the ore deposition. The entire absence of ore bodies at a distance from diabase contacts precludes to the writer's mind the hypothesis that the ore-bearing solutions came up through vents other than those occupied by the diabase.

The solutions may have come up through the diabase vents in two ways: (1) they may have accompanied the diabase magma at the time of the intrusion, or (2) they may have come up after the intrusion and partial solidification of the diabase. If the first is the case the solutions were forced out of the cooling and crystallizing magma into the surrounding sediments, both above and below, and replaced the easily altered material, that is, the calcareous beds. If the second is the case, the solutions came up through openings in or close to the original vents, and may have spread through the main diabase mass and permeated the sediments along its contact replacing the calcareous beds in them, or they may have been confined largely to the contact of the diabase and the sediments without penetrating far into the main mass,

but permeating the more porous sediments for considerable distances from the contact.

Several arguments may be cited in support of both of these hypotheses, but it seems that the first is the more probable. If the solutions had come up after the partial consolidation of the diabase, one would expect to find evidences of its passage through the diabase such as iron ore veins in the diabase or metamorphism of the diabase adjacent to fissures along which the solutions passed. One might also expect to find evidences in the sediments of two stages in their metamorphism, first by the intrusion of the diabase and second by the action of the ore-bearing solutions. The ore-bearing solutions might be expected to have broken through the sediments locally and to have formed ore deposits far away from diabase masses. None of these conditions are apparent. The ore is regularly associated with the diabase contact and the diabase is free from iron ore veins and evidences of local alteration due to metamorphism.

On the other hand, if the solutions came directly from the diabase masses with which the ores are associated, the presence of the latter directly at the contact and their absence away from the contact is explained. Yet though this hypothesis is the more probable it does not explain sufficiently the localization of the ores at various places in the Mesozoic belt, that is, their presence in places along the contact and absence elsewhere. The localization in the Dillsburg district may be explained by the presence or absence of calcareous beds, but this explanation, according to Spencer, does not apply throughout the Mesozoic region. It is possible, however, that the explanation lies in the fact that solutions given off by different intrusive masses or in different parts of a single intrusive mass may have differed materially in composition. At any rate such localization is not an exception but is rather a characteristic of many contact deposits. One might also expect to find marginal facies in the diabase masses such as a basic edge, which, while they occur in the Dillsburg district have not been proven to be present. Many contact deposits are known, however, near which such marginal facies do not occur, there-

fore the argument is also not a valid one against the hypothesis of contact deposition.

The solutions may be presumed then to have come up with the diabase magma at the time of its intrusion and to have been forced out during its cooling and crystallization. All that is known of the nature of the solutions at the time of their entry into the sediments is that they carried much iron and some alkalies, largely soda, but contained little or no silica. The presence of the alkalies and iron is shown by the occurrence of feldspar and magnetite, respectively. The lime and magnesia necessary for the formation of the ferro-magnesium minerals and the silica necessary for the silicates were probably derived from the sediments.

The solutions were forced out from various parts of the cooling mass, above as well as below, and penetrated the sediments for varying distances from the contact. In the more calcareous beds iron ore and numerous metamorphic minerals were developed while in the less calcareous beds numerous metamorphic minerals were developed but no replacement by iron ore took place. In the calcareous beds the calcium carbonate was probably for the most part replaced by iron oxide, while the impurities, largely silicates, were either simply recrystallized or were metamorphosed into other minerals. The minerals formed with the magnetite, at nearly the same time, were pyrite, pyroxene, feldspar, epidote and garnet, while a little later calcite was deposited in veins and cavities and probably represents most of the unreplaced calcium carbonate. Later oxidation and decomposition of these minerals has resulted in the formation of limonite from pyrite, chlorite from pyroxene and sericite and quartz from feldspar.

MINERALOGY OF THE ORES AND ASSOCIATED ROCKS.

The Mesozoic sediments of the Dillsburg region in their unmetamorphosed state consist of red sandstones and shales with beds of limestone and limestone conglomerate, the latter consisting of pebbles of white, pink and blue limestone in a calcareous matrix. In the iron ore area these sediments are all metamor-

phosed so that their original character is in most cases unrecognizable. They consist largely of baked shales and fine-grained sandstones of prevailing brownish-yellow, pink, or light green color with interbedded light green calcareous layers, some of which show the original conglomeratic structure of the limestone conglomerate, while others have a uniform crystalline texture. The calcareous beds are locally replaced by iron ore near the diabase contact, but the partings of baked shale and sandstone between them are only metamorphosed and not replaced by iron ore.

The ore beds consist largely of two varieties of material (1) granular or finely crystalline magnetite, (2) fine-grained, metamorphosed rock of greenish color. These are intermixed in the most irregular manner; locally the magnetite is predominant but in general the metamorphosed rock is more abundant. The gangue minerals occur both in the ore and in the metamorphosed rock. The magnetite and the gangue minerals are generally more coarsely crystalline than the metamorphosed rock and in some places they have sharp contacts with it, while elsewhere they grade into it. The magnetite is usually intimately intermixed with the gangue minerals, in fact it is but one of the metamorphic minerals. Locally, however, the gangue minerals occur in the metamorphosed rock with little or no associated magnetite, while elsewhere masses of magnetite occur with few or no gangue minerals. The metamorphosed rock in the ore beds consists of a finely granular mixture of metamorphic minerals, its mineral composition being very similar to the barren partings of baked metamorphosed rock between the ore layers.

The baked sandstone and shales consist largely of a finely granular aggregate of pyroxene (augite), quartz and feldspar (albite). Locally along some layers there are developed larger crystals of garnet (probably andradite), pyroxene, pyrite, and rarely magnetite. In many of the beds the porphyritic crystals are entirely absent, while elsewhere they are very abundant. The pyroxene and quartz are about equally abundant in the fine-grained matrix, while the feldspar is very subordinate in amount.

The pyroxene occurs in small grains in a matrix of quartz. Garnet is apparently entirely absent in the groundmass, but is the most abundant of the porphyritic crystals. The garnet crystals contain included grains of quartz and pyroxene like those forming the groundmass. Most of the garnets have sharp outlines but some grade into the groundmass. The porphyritic crystals of pyroxene are much less abundant than those of garnet. Pyrite crystals are quite abundant locally, and near the surface are generally partly altered to limonite.

The metamorphosed rock in the ore layers is very similar in composition to the baked shale and sandstone in the partings between the ore beds. Pyroxene, feldspar, and quartz occur in it in varying abundance in different places. The ore and gangue minerals are developed through it irregularly and are distinguished from it by being more coarsely crystalline. Several of the minerals are common to both. The following are the ore and gangue minerals in order of their importance: magnetite, pyroxene (augite), chlorite, pyrite, calcite, feldspar (albite), epidote, sericite, quartz, garnet (andradite) and limonite.

Of these magnetite, augite, pyrite, albite, epidote and garnet are the metamorphic minerals; calcite is a later infiltration; chlorite is formed largely by the alteration of pyroxene; sericite and quartz are decomposition products of feldspar, while limonite is formed by the oxidation of pyrite. Garnet, pyrite, pyroxene and magnetite, the first minerals developed, appear to have been formed approximately in the order named. They were followed by feldspar and later by epidote. The relation of the epidote to the metamorphic minerals is not clear, but it was plainly developed earlier than the chlorite and the other alteration minerals.

Magnetite, as has been stated, is the most abundant of the ore and gangue minerals. Some magnetite grains show sharp crystal outlines, while others are very irregular. They have inclusions of pyroxene, pyrite and garnet, and rarely feldspar. The included pyrite, garnet and pyroxene in many places show sharp crystal outlines, while the feldspar is irregular.

Pyroxene is the most abundant of the gangue minerals and

occurs intimately associated with the magnetite. It varies from light green to colorless, and some of it is slightly pleochroic. Most of it is fresh and unaltered, but locally a slight alteration to chlorite has taken place. In some places chlorite is very abundant in the ore and at such places little or no pyroxene is found.

Chlorite occurs in radiating crystal aggregates, many of which show a deep blue interference color in the center and yellow on the outside due to a difference in composition. Where chlorite is abundant pyroxene is almost absent, indicating that most of the chlorite is probably an alteration product from the pyroxene.

Pyrite is disseminated in crystals through the magnetite and gangue minerals and varies in abundance in different parts of the ore beds. It was evidently formed before the magnetite, as perfect little crystals of it are found imbedded in masses of magnetite. In the surface ore it is partly or entirely altered to limonite.

Calcite is found in cavities or veins in the ore and metamorphic minerals, and was the last of the original minerals formed. The alteration of the pyroxene and feldspar occurred mostly after its deposition, as is shown by infringement of their alteration products on the calcite areas. It is very abundant and widespread, probably more widespread than chlorite.

Feldspar, while characteristic and widespread is not very abundant. It occurs both in the ore and in the associated metamorphosed rock. Nearly all of the feldspars are cloudy and a large proportion of them are entirely altered to sericite and quartz. They occur in cavities and frequently in cracks in the older minerals. Many of the feldspars are untwinned, but some of them show characteristic albite and pericline twinning.

Epidote is not as widespread as most of the other minerals, but locally it is quite abundant. Its mode of origin is not clear from its occurrence; some of it is associated with the decomposition products, but some of it is apparently original.

Sericite or white mica, probably in part soda mica, is present simply as an alteration product of the feldspar. It occurs in small flakes and with it there are frequently associated small

amounts of quartz. The great bulk of the feldspar alteration material, however, is white mica.

Quartz occurs in very small amounts only as a secondary product of the feldspar. No original quartz was noted among the gangue minerals.

Garnet, while abundant in the baked shale partings is very rare in the ore beds. Where it occurs it is found in small crystals imbedded in magnetite or pyroxene.

Limonite occurs near the surface as an oxidation product of pyrite.

SALT MARSH FORMATION NEAR BOSTON AND ITS GEOLOGICAL SIGNIFIGANCE.[1]

CHARLES A. DAVIS.

INTRODUCTORY.

Among the minor physical features of the New England coast are the salt marshes, impressive only as the observer follows rather closely the ocean border and notes the very considerable areas of land occupied by them. As scenic features they are monotonous and uninteresting in the extreme, because of their lack of relief and uniformity of appearance. Having seen one salt marsh, and made observations necessary to fix its few peculiarities in mind, the student of physiography apparently thereafter feels that he can devote his time more profitably to more complex phenomena, while students of other phases of geological science seemingly have rarely, if ever, given the subject of the origin of these terranes any special attention. The writer, having devoted some time during the past field season to the study of the way in which the New England salt marshes have originated, and finding much that interested him in the course of his work, and that was apparently new to American geologists, asked for permission to present the substance of his work at this time, thinking that it might also prove interesting to some who might be present.

A glance at the topographic sheets covering the neighborhood of Boston, as, for example, the Boston Bay and the Boston quadangles, shows that salt marshes are prominent features of these areas, covering considerable surface. Culturally, also, they are conspicuous, being generally unutilized for any purpose except for making a small amount of inferior hay, hence they are practically desert places, except where land values are sufficiently

[1] Read at the Boston Meeting of the Geological Society of America. By permission of the Director of the U. S. Geological Survey.

high to make it worth while to raise the surface above high tide level for building purposes, or to dike out the tides.

DESCRIPTION.

Salt marshes are flat areas, often of considerable lateral extent, so situated that they are overflowed at frequent intervals, typically, twice daily at high tide, by the salt water. The soil of these marshes near the top is a coarsely fibrous silty peat, usually becoming darker and less fibrous as it is penetrated, and like all aggregations of vegetable débris, quite easily eroded. Because of the ease with which erosion takes place, the salt marshes are penetrated by extensively meandering and branching tidal channels, known as "creeks," through which the salt water reaches and flows away from the remotest parts of the marsh. The marshes are also often crossed by streams of various size, which have their origin in the high land around them, and it is characteristic of such streams that their channels increase greatly in size and width from the point where they enter the marshes, so that the latter often takes on the character of an apparent border to an estuary.

The creeks that originate in the marshes often seem to take rise in a poorly drained part of the marsh at some point remote from the mouth of the stream but have doubtless been formed by tidal erosion from the inlet side, and unquestionably some of these are still cutting back into the marshes, since the crest of the tidal wave reaches these remote parts very late, and long after it has passed the point of its entrance, so that falling tide is accompanied by rapid outrush of the water through the creeks. The creeks themselves are characterized by vertical banks near their head, and by more sloping ones towards their outlets; sometimes the vertical cuts, when freshly made, show the structure of the marsh, but generally, the banks, even where steep, are masked by a coating of silt, and the turf formed by the stems and roots of the characteristic vegetation that covers them.

The surface of all salt marshes of the region is covered by a growth of a few species of herbaceous plants, of which the domi-

nant and characteristic species are grasses, with a less important representation of sedges and rushes, and, locally, invasions of other types. Many salt marshes in the area under consideration also have "islands" of high land, either of drift or rock, standing more or less above the general surface, and these frequently are, or have been, tree-covered, so that they loom conspicuously above the marshes.

The salt marshes are also usually sharply delimited from the adjacent high land, not infrequently where the conditions are favorable, by a wave-cut bank, or relatively sharp slope, although in some places, there is an almost imperceptible gradation from salt marsh to fresh. In general, however, it may be said that there is a sharp, and even to the inexperienced, an easily distinguishable line of demarcation between the salt marsh and its environs, that shows the level to which the salt water reaches. They are thus units, generally sharply marked off from the surrounding land forms by the line reached by the maximum high tides.

THEORIES OF ORIGIN.

Apparently the subject of the origin of these features of coastal topography has given but few writers on geology food for thought. They have been mentioned but seldom, and it has been supposed, since the papers by Shaler, beginning about 1885, when his "Sea Coast Swamps" appeared in the 6th Ann. Rept. of the U. S. Geological Survey, that there was little to be learned from them.

According to Shaler's hypothesis, for, though supported by diagrams, sections and positive statements, his account of the way in which salt marshes develop, is little more, they are formed in shallow water in bays, estuaries or barrier-protected lagoons: (1) By the upbuilding of the bottom by sediments, until the water is sufficiently shallow for the common eel grass, *Zostera marina* L., one of the few seed plants growing wholly submerged below salt water, to become established. This forms dense growths on the bottom and adds a quota of organic matter to the deposit by its own activities and by sheltering other organisms, both plant and animal, and also entangles and precipitates to the bottom on

which it grows, suspended inorganic matter, which constitutes the greater part of the accumulations formed by its agencies. (2) By the encroachment of certain species of grasses, capable of enduring exposure to salt water, into the shallows already existing, or those formed by the eel grass, and there form a tough, peaty accumulation that builds up nearly to the level reached by the high tides; because the plants nearest open water form a filter that intercepts a large amount of suspended matter, the deposit grows faster there and assumes a terraced form, and in this form advances more or less rapidly upon the area already prepared for it by the eel grass.

This is really the way in which it would seem that our salt marshes were formed, from the external evidence presented to the casual observer. In many shallow places, in channels in the creeks, estuaries and even off the open beaches along the exposed coast, just below low-water mark, eel grass is found forming deposits of mud and organic matter mixed. It sometimes comes ashore in vast quantities on certain parts of the New England coast and at one place forms the basis for a manufacturing industry of no mean importance. Again, between the channels in which the water stands permanently in bays and similar areas along the coast, and the high-water level, are bare mud flats, and these are generally bordered by a more or less dense growth of the grasses mentioned above, which often do occupy a marginal area of turfy, silty peat, that is roughly, or even definitely, in the form of a terrace. Hence it is obvious if this external view is the only one taken, that the theory given explains the facts and is sufficient, and, so far as the writer can learn, it has generally been accepted as such, without comment or criticism.

The Study of Salt Marsh Sections.—The adequateness of this theory is relatively easily tested by the actual study of the structure of salt marsh deposits in a sufficient number of places to be certain that the original structure has not been disturbed.

If the theory presented by Shaler accounts for the deposits, they should give an average, or typical section, which would have sand, silt or mud at the bottom, up to about twelve feet below

low-water mark; between these two levels the easily recognizable remains of the eel grass, mixed with silt and the shells of mollusks and other marine organisms, should characterize the strata. Above this, should be found another layer of silty mud, up to the level above which the salt water grasses grow; then the remains of these plants should be found in constantly increasing numbers, until they form the bulk of the stratum, since observation shows that there is a level above the low-tide mark, below which these plants do not go, and at the greatest depth to which they grow, the number of individuals found is small compared with that at which the species finds optimum conditions of growth; at the top of the section should be a distinct turf, formed of the characteristic plants growing on the surface, which, because of the very definitely fixed habits of these species, would be, relatively, very thin.

Actual Structure of Salt Marshes as Determined by Sections.—In the course of the field work mentioned above, practically all of the salt marshes in the Boston and Boston Bay quadrangles were examined, primarily to determine their possible economic value, and were tested in many places with some care to ascertain the exact origin, and in none of them was such a section found as that outlined above. In many cases it was found that the deposits below the surface, instead of containing eel grass and salt thatch remains, was entirely composed of the very different and definitely recognizable sort of vegetation that never grows where salt water reaches—*i. e.*, the deposits were largely of fesh water origin. The structure of these marshes also often showed salt water intrusion in varying degree in different parts of the same area, the deposit of the salt marsh material being progressively thicker as the ocean was approached.

Another notable thing, and one vitally affecting the theory cited was that the salt water deposit, which was easily recognizable, was made up, not of the plants like eel grass, that can grow only below low water, or those that can grow at half tide, but these which at present grow at or near the high-tide level.

If no fresh water deposits were found in the section, as was the case in a few of the marshes visited, the peat found still did

not exhibit the structure indicating that it had been built up as described, but was made up of the characteristic parts of the species now growing on the surface, often to such depth that the bottom of the stratum was below the present low-water level.

The Growth of Plants in Relation to High-water Level.—Before continuing the discussion further and weighing the value of the evidence presented, it may be well to consider briefly the relations of plants to their environment and the significance and importance of the criteria which the presence of their remains in certain relations furnish.

In order to make any growth, plants require certain gases, soluble mineral substances, water, light and heat. Each plant type is fixed within certain narrow limits in its requirements for each of these factors of growth, although every species may differ from others in the range of its limits; there is a well defined minimum in the quantity of each that it must have, without which it will not grow at all, and a maximum, which, if exceeded, as surely inhibits its growth. The minimum for some species is large, but, in many cases, it is apparently very small, so that species are seldom starved for the want of the minute quantity they need.

For example, the amount of certain mineral compounds essential to the growth of plants is so small in some soil waters as to be inappreciable to ordinary methods of chemical analysis, except after much concentration, yet such soils may support an abundant and varied plant population. Water, obviously so essential to the growth of all plants, when too abundant, acts unfavorably, and the great majority of plant species of a given region are closely limited in their distribution by the relation of the ground water level to their root-systems; light, beyond their ability to protect themselves from its injurious effects, is as effectual in preventing many plants from growing in certain situations, as its absence is in controlling the distribution of others.

It must also be borne in mind that there are certain mineral, organic and gaseous substances that may be beneficial to, or tolerated by, most plants in very minute quantities, which are

present in most soils and soil waters, but which become toxic when a very small maximum of tolerance is exceeded.

For convenience in discussion, it may be assumed that the two factors of growth, of those mentioned, that are of most importance in controlling the distribution of plants in a given locality in the region under discussion, are the relation of the ground water level to the soil surface and the presence of poisonous salts in considerable, but varying, amount in the soil water. At the outset, it is evident that more plants will be kept from growing in those places where both factors are operative than where but one is to be met. Thus, observation shows that a swamp adjacent to a salt marsh, in which the ground water level may be equally high, has a much greater number of species of plants and often more individuals to the unit of area, than the marsh, and, since the only variable is the amount of dissolved mineral matter in the soil waters, to the excess of this in the salt marsh may be attributed the paucity of its flora; the two unfavorable factors exclude more species than the single one.

Following this line of reasoning, it is not difficult to establish the fact, that, if it is known what the tolerance of plant species to each, or both, of these controlling factors is, when their remains are found preserved in such relation that they are manifestly in place as they grew, the conditions under which the types lived can be accurately reconstructed, and it can be affirmed with the greatest positiveness that they could not have grown under other conditions.

It is clear, therefore, even to the casually interested observer, that a necessary preliminary to the satisfactory study and interpretation of the deposits found in salt marshes, is a working knowledge of the morphology of the plants most likely to be found well preserved in the deposits, so that they may be readily recognized, and certainly determined, and of the conditions under which they grow at the present time.

The existing flora of salt marshes, as has been pointed out, is made up of a few species of seed plants, of which grasses, or grass-like types of plants, are the most important, because the most numerous, but it requires only a short study to convince

one, that all of even these few types are not equally able to endure exposure to and submergence by, the tidal water or are equally fond of it, for, by watching the rise of a single tide, it will be found that some species are covered long before others, while those parts of the surface of the marsh on which the greater number of species grow, will not be reached at all by even the crest of the average tidal wave. In other words, the plants of a typical salt marsh will be found to be arranged in well-defined zones, the limits of which are marked, apparently, by the length of time the area occupied by each is covered periodically by the tides.

A rough system of classification of the tides would at least make four and probably five distinct phases of high tide: (1) The ordinary high tide, occurring twice daily, in which the crest of the tidal wave reaches and covers the surface of the salt marshes to the depth of an inch or two, and from one half to two hours for each tide. (2) The semi-monthly spring tides, due to combined lunar and solar tidal waves, during which the water rises some inches higher than usual, and floods part of the marsh surface not reached by (1). (3) The equinoctial high tides, occurring about the time of the equinoxes, which, a few times in the year, cover still more of the marsh surface and increase the exposure of the lower levels to salt water. To this may be added also the high tides of the winter solstice. (4) Storm tides, in which spring tides are combined with strong inshore gales. During these, which occur irregularly, the salt water reaches its maximum depth of three to five and a half feet over the general surface of the marshes and spreads to their farthest limits, flooding areas not otherwise reached by salt water. A fifth stage, of very low-crested tidal waves, due to a combination of low neap tides and violent and prolonged off-shore winds, might also be mentioned, during which the average surface of the marshes is not reached by salt water, but this is probably not important or even significant in controlling the distribution of the marsh flora.

Turning now to the flora, the zones into which the terrestrial plants separate themselves, beginning with the lowest, which,

because it endures the most adverse conditions, is the simplest, are as follows: (1) The salt-thatch zone, which forms the covering of the banks of the tidal creeks, often to the bottom of the slope bordering the tidal flats and, where these are well-drained, which is rare, or where they are peaty below a thin covering of silt, sometimes intruding upon them. This zone is limited downward, very nearly, by half-tide mark, and, at the top, by the zone next higher, that is, it lies above the area covered more than half the time by salt water, and below that which is sometimes not covered at all. The sole seed-plant occupying this zone, except for occasional stragglers from the zones above, is the tall, coarse, rank-smelling salt thatch, *Spartina glabra* Muhl. var. *alterniflora* Loisel and Merr., a plant typically having large, hollow, jointed stems, broad, yellowish-green leaves and growing from two to four, or even six feet tall. It seeds abundantly and sends strong, thick, very characteristic, underground stems into the substratum on which it grows, in all directions, and from these, at nodal intervals, spring the long, fibrous, much-branched roots. The parts most often preserved in the deposits on which it grows, are the underground stems and those parts of the aërial branches that do not get above the surface of the mud. These are easily distinguished from other plant remains, by their size and color, which remains a bright, clear, straw color for an indefinite time. The aërial parts, stems and leaves, after the growing season is over, become very brittle and are broken off by the waves and ice, and, being very buoyant, often accumulate in great quantities along the high water line, or are carried out to sea; apparently they do not enter into the deposit where they grow, to an appreciable extent. A small variety of this type, a foot or two tall when in fruit, grows also on the parts of the marsh surface where there are slight depressions, or where the drainage is so poor that salt water stands for the greater part of the time.

The remains of these plants may be found penetrating and mixed with those of other types, but in typical beds, laid down within the limits of the zone described, mineral matter generally much exceeds the vegetable, and the other deposit does not even approximate peat in character. It is not usual to find deposits

that can be attributed to this plant's activities having any considerable lateral extent, and often the terraces on which it grows have been found to be formed of the remains of entirely different types.

The next zone above the salt thatch zone is the general surface of the marsh, usually covered from one to four hours each day by salt water, which rises an inch or two only above the surface. The conditions here are not quite so severe as on the area just described, as the daily period of submergence by water is shorter, and drainage conditions are better, therefore a large number of species of plants are found, but of these but two are numerous enough to be entirely characteristic and significant.

These are both grasses, with no distinctive common names, being called salt marsh grasses, but so different from the salt thatch that there is no possibility of confusing any deposit into which their remains enter, with that which it forms. These plants are *Spartina patens* (Ait.) Muhl. and *Distichlis spicata* (L.) Greene, both typically short, from six to twelve or fourteen inches tall, with rather slender, tough, wiry stems, and dull, grayish-green, slender, involute leaves, that are made still grayer by the coating of salt and silt which covers them. Besides these aërial parts, they have an extensive system of slender, tough, underground stems, from which arise long, fibrous, branching roots; together, these form a turfy structure, that is a mass of intermingled fine fibers, usually whitish or grayish, from intermingled silt, that cannot be mistaken for any other form of vegetable deposit with which it is likely to be associated. It differs from the turf formed by sedges in the persistence with which the underground stems retain their form and individuality, instead of collapsing and flattening, in the lack of the remains of leaves and aërial branches, in color, in the absence of definite lamination, in the amount of silt generally contained, and, more than all else, in the presence of the white or light-colored finely branching roots, which penetrate the mass in every direction and make up the great bulk of the material. The leaves and stems of these two salt marsh grasses are more persistent than those

of the salt thatch, but, during the winter they are largely removed by ice which covers the surface of the marshes and is lifted by the higher tides, and by the action of the winds and tides after those that escape removal in this manner have become brittle with exposure and are broken off. From these causes apparently, but a small proportion of them becomes incorporated in the turf.

While these two most prominent and significant species of the general surface flora of salt marshes are able to grow on the levels reached only by the higher tides, and thus become constituents of the flora of the upper zones, they are often entirely eliminated from these by the competition of more vigorous species, and hence lose their importance as characterizing types.

These remaining plant zones, occupying the upper levels of the marshes, are seemingly of little significance in marsh formation and it is unnecessary to describe them here. They are, however, well defined and are characterized by the presence of a more varied flora than either of the other two, but each has some species that would give character to deposits made by them, which sharply differentiate these from those mentioned, or from most fresh water deposits that might be associated with them.

Details of sections would be tedious here, even if there were time to present them, but more than one hundred test holes were made in various marshes during the studies on which this paper is based, and, in most of these, samples were collected from top to bottom and examined from each foot of the deposit penetrated. The marshes proved constantly of two types, as already mentioned: (1) Unquestionable fresh-water deposits, often with considerable depth of woody material, including the stumps of large pine trees, near the surface and for a few feet below; on this material was superposed a stratum of salt marsh turf which was progressively thicker as the test holes were made from the shores of the marsh seaward, and (2) salt marsh turf made up of one type of material throughout; this was easily identified, as of precisely the same structure and origin as the turf on the present surface of the marshes.

It is obvious even to the least informed observer that pine trees

and most woody plants do not grow where their roots are covered by salt water, and that none now grow where salt water reaches them even occasionally. Hence, if their remains are found buried in salt marshes, or even in places in which the salt water reaches them at high tide, it is easily understood that such occurrence is either a record of a higher sea-level than when the trees were growing, or, what would give the same effects, of subsidence of the land surface, since that time.

In accordance with the laws governing the distribution of the plants on salt marshes, it is equally certain that their vertical distribution with regard to the tidal level is even more narrowly limited than that of the pines, for, while the latter may not grow below any level to which the salt water reaches, they have a very wide range above it, and the ground water level in the soil, growing from very wet to very dry situations. On the other hand, the salt marsh grasses characteristic of the surface zone of the marshes, are very closely limited to a vertical range of not more than three, or, at most, four feet, and are most abundant within vertical limits of about two feet, as they are unable to endure a daily submergence of more than about four hours on the one hand, and on the other are crowded out of the levels not reached by the average high tides, by other species.

If it is assumed that these facts are established, and that the changes of level are due to coastal subsidence alone, and not to rise in the sea-level, or other change of the sea relative to the land, it is apparent that the remains of these grasses become most significant in any deposit in which they occur, since they furnish definite evidence of the levels to which the tides reached at the time when the plants were alive, more exactly than any other records now available. If they are found below the limits to which the plants can grow, and are clearly in undisturbed deposits, there has been subsidence of the part of the coast where they are found, the amount of which is measured by the depth below mean high water at which they are found, plus or minus not more than two feet. It is admitted that the recognizable remains of any plants which must grow above the reach of the salt water, if found in situ below the sea-level, give as good

records of the fact of subsidence, and there are many places along the eastern coast of the United States where stumps and roots of trees are known to occur below low-water mark, so that it is already well known that there has been a general coastal subsidence in very recent geological times.

But the geological significance of thick beds of peat formed almost entirely of the turf built by *Spartina patens* and its associates, is more than a mere record of subsidence; it shows the amount of sinking, since the starting plane is known within very narrow limits. Moreover, this type of deposit gives a record that cannot be disputed, of the rate of subsidence and its uniformity. Where this material occurs in beds several feet thick, extending, as in several cases noted, to below the present low tide level, in the midst of undisturbed marshes, the only way in which it can be accounted for is, that subsidence equal to the thickness of the beds, has taken place, and at the rate at which the grasses and silt built up, for, if subsidence had gone on faster than upbuilding, the *Spartina patens* would have disappeared and its place be taken by the very different *Spartina glabra* or by marine muds, with mollusks, shells and possibly the peculiar remains of the eel grass. If, on the other hand, the movement went on more slowly than the accumulation, the surface of the marsh would finally be raised above the reach of the ordinary tides, and the characteristic plants of other zones would appear, which would give a different structure and appearance to the deposit. The same thing would also happen, but more rapidly, where the subsidence ceased, and it would be a matter of but a comparatively short time when the salt marsh surface would be built above the level where the tides would no longer reach it; a fresh water marsh would be established, and, later, a tree-covered swamp.

Oscillation of the continental margin would also be quite definitely recorded in salt marsh deposits, and at other points than the locality now claiming attention at least one slight upward movement, followed by gradual subsidence, seems indicated by the presence of a well-defined series of fresh-water peat beds including tree stumps, between two layers of *Spartina patens*

turf, the lowest of which is below low water mark. These deposits were found under such conditions that the hypothesis that the fresh-water peat was formed in a freshened lagoon behind a barrier beach seems entirely inadequate to explain the facts. No such record was found in the vicinity of Boston, however. The salt marshes examined all give evidence of the sort cited, of subsidence that has been going on at a rate not exceeding that at which the surfaces of the marshes are being raised. The deepest deposit found that was plainly made up of *Spartina patens* turf, was in a small marsh at Nahant, where at fourteen feet below the surface of the marsh, sandy bottom was struck, above which was about two feet of blackish-brown peat of distinctly fresh-water type, and twelve feet of salt marsh turf. As the writer interprets this, Nahant, at the time when there was a fresh-water marsh where the salt marsh now lies, was, at least, sixteen feet, or more, higher above the sea-level than now. It is interesting to note in this connection, that, in a marshy tract, behind a barrier beach on the sea front at Nahant, there are numerous pine stumps buried in the fresh swamp-pasture turf over part of which the salt water does not yet rise, but, in lower places, *Spartina patens* is already established and has formed a thin turf. Here are two salt marshes, alike in externals, but of very different structure, yet the last mentioned has very recently been invaded by saline waters, while the first is, comparatively, very old.

If it were necessary to carry the argument further, it would be easy to cite as the evidence against the correctness of Shaler's theory, the very irregular bottom of some of the Boston salt marshes. For example, the Mystic River salt marshes, where the marsh deposits are very shallow over considerable areas and quite deep in others, with gravel islands and points rising above the surface. The sub-soil under a considerable part of the Wellington side of the marsh, where the vegetable deposit is often very thin, is a more or less sandy gravel, which, in places, has been removed for economic uses, and is of such a character that it could not have been formed in an estuary, while the irregular surface equally precludes such an idea. The record is made more

positive here, as in many other cases, because roots and the remains of woody plants occur abundantly in situ, in the top layers of the gravel below the salt marsh turf, and not marine muds, interspersed with mollusk shells and other salt-water débris. The evidence is strengthened still further by the occurrence of the remains of a pine forest buried in the same marsh, not far from the old clay pits of the brick yard near Wellington.

Salt marshes in the area under consideration, are then, in the opinion of the writer, features of, and an accompaniment to, coastal subsidence. They furnish an excellent record, so far as it goes, of the amount of the present crustal movement, and give the most definite measure we have of its persistence and rate, since it is manifest that, if the rate of growth of the peat can be determined, the rate of subsidence will be known, at least so far as these deposits extend, for the two are equal. This rate has not yet been determined but it is probably slow, perhaps less than a foot in a century.[1]

Unfortunately the older parts of these salt marsh deposits are seldom preserved, for as the tidal waters penetrate farther and farther inland, as subsidence continues, and the areas submerged get wider, waves, strong currents, ice and other erosive agents attack the easily eroded vegetable accumulations, and they are either removed entirely, or much modified in their relations, especially where the underlying material is of fresh-water origin. Erosion goes on with greatest rapidity when these marsh deposits are subjected to the attack of the ocean waves as the result of a landward movement of every part of the coast line, and it is only now and then that fragments of the older parts of these deposits have survived such attack and appear in favored localities below the low water level, where, from time to time, they may be seen when they are bared by a very low run of tides.

In conclusion it may be said that the pure salt marsh deposits,

[1] Mr. J. R. Freeman, in Appendix 20, Rept. Committee on the Charles River Dam, 1903, gives the rate of subsidence as determined by comparison of old bench marks, as about 1 foot per 100 years. Some indications were noted in the salt marshes pointing to a more rapid rate at present than formerly, but these were not worked out.

such as the *Spartina patens* turf, are generally very silty or even sandy. The tidal waters, especially during stormy periods, carry much fine sand and silt, part of which is left on the surface of the highest levels reached by the tides, and not a little, on the grasses themselves. The generally silty character of the peat thus formed, suggests that it may be erroneous to attribute to similar coastal conditions to those existing on the present salt marshes, the formation of thick beds of usable coal during other geological periods, for it seems probable, from the enormous beds of sediment laid down in such times, that the sea waters then were even more silt-burdened than at present, and, if this were the case, salt-marsh deposits of these periods would be even more intermixed with mineral débris than those now existing, which generally are too high in ash-forming constituents to be of much fuel value. Hydrogen sulphide is found in great abundance in peat beds to which sea water has access, apparently as the result of the action of certain bacteria on the sulphates contained in the water. The gas reacts on the iron compounds contained in the silt and other mineral matter carried by the salt water to the marshes, and forms iron sulphides which eventually are deposited as pyrite, and this mineral is reported abundant in the mineral part of salt marsh peat.

Similarly, other bacteria than those mentioned decompose part of the hydrogen sulphide dissolved in the water in open marsh pools and leave the sulphur free. This reaction seems to be confined to the pools mentioned, and the amount of sulphur thus seggregated is so small that it forms no reconizable part of salt marsh peat, but the first mentioned action is of sufficient importance to be taken into account in explaining the extensive occurrence of pyrites in coal beds or in their immediate vicinity. It should be noted in this connection that, while hydrogen sulphide is seldom found in peat formed under fresh water, if beds of this character are exposed to salt or brackish water after they have been laid down, they become as strongly impregnated with the gas as does the salt marsh peat. It is apparent, therefore, that the presence of pyrites in coal would not necessarily indicate

marine origin, for the beds containing it could be interpreted to give the presumption of invasion of the original deposits by tidal waters before consolidation sufficient to prevent free percolation and bacterial action had taken place. This would be especially true with regard to finely deseminated pyrites, but might also be applied to the dendritic, nodular and other forms of the mineral which would be formed as the result of solution and transportation of the original material.

Other general application of special marsh phenomena that might be made to geological problems could be mentioned.

THE DEPARTMENT OF MINES OF CANADA, ITS ORGANIZATION AND ITS WORK.

ALFRED W. G. WILSON.

The Department of Mines of Canada, as at present constituted, was created by an Act of the Parliament of Canada assented to on the twenty-seventh of April, 1907, and it has already entered on the fourth year of its history. Even now the plan of organization and the functions of the various branches and other subdivisions of the department are matters not clearly understood, even by many in Canada who are closely associated with the mining industries and with the work of the departmental staff. The present article, written at the request of the editor, is intended to place before the readers of ECONOMIC GEOLOGY a concise and accurate statement of the present organization and functions of the department as defined by the statute under which it was created; it is prefaced by a brief historical sketch of the more important events which led to the organization of the department.

The Geological Survey of Canada, the forerunner of the present Department of Mines, first constituted in 1842, was organized only after some ten years' active propaganda on the part of interested persons. During its early years, the work of the survey was confined largely to general scientific geologic work, much of which had, however, an economic bearing. The investigations embraced only parts of the provinces of Ontario and Quebec, which then constituted Upper and Lower Canada. After confederation (1867) its work was extended to include the Maritime Provinces and, later, the whole of western Canada, and this with only a very slight increase of staff at that time.

During the next interval of a little more than two decades, general areal explorations were carried on in various parts of Canada; a few men inadequately equipped were required to explore the vast domain of half the continent.

In the early eighties of the last century, persons who were immediately concerned in the development of the mineral resources of Canada began to importune the government to give more attention than had been given in the past to the collection of statistical and other information relating to these resources and to the mining industries of the country. The matter also seems to have been a subject of discussion among the interested members of the British Association for the Advancement of Science, which met in Montreal in 1884, for we find that members of this association, at this time, strongly urged that prompt steps be taken to supply this want. Two years later, in 1886, a strong and influential deputation of mining men and others interested in mining, representing all parts of Canada, waited on the Minister of the Interior, with a request that a "Bureau of Mining and Mineralogy" be established. Their memorial reads as follows:

Whereas, it is believed that the information and statistics regarding mining and mineral developments in Canada furnished by the Dominion government are not in keeping with the desire of those interested in such developments, and are neither sufficient nor accessible enough to supply the public with full, authentic and prompt information on these subjects; we do, therefore, wish to respectfully bring to the attention of the government the following desires of a section of our community:

1. To have full and reliable information of the mining and mineral developments, and statistics connected therewith, for the whole dominion, published each year, as soon after the end of the year as possible.

2. To have a medium through which information relating to our miners in all parts of Canada can be given to the public—such medium to be a monthly publication.

This would have a tendency to bring our mining industries constantly before the public and to educate them to take an interest in sound and legitimate mining enterprises, besides giving to the world at large constant information about mineral development in Canada compiled from records and reports of a mining bureau under government control which would be authentic and reliable.

This memorial also contained five numbered suggestions, the first and most important of which reads as follows:

That a mining and mineralogical branch of the Geological Survey be established which will publish its reports separately and annually, such a branch to be presided over by an independent officer.

These recommendations seem to have been accepted and acted upon, for in the following year, 1887, was published a report entitled "Statistical Report on the Production, Value, Exports, and Imports of Minerals in Canada, during the year 1886 and previous years," the first report of its kind. Subsequently, a special Mines Section of the Geological Survey was organized to collect and publish information of this character.

Statistics and the various methods of compilation seem always to be a bone of contention and Canadian mining statistics have been no exception. Again, the rapid expansion of the country and the consequent growth of the mining industry create new demands. In a new country, such as Canada, with her vast extent of territory, largely unexplored, where new industries are constantly being organized to exploit her natural resourcees, the demands upon the government for information and assistance in the establishment of these industries are both insistent and persistent. There are many enterprises where technical knowledge and skill are required, more especially in the initial stages, and there are many occasions where a paternal government can, in various ways, assist its constituents with technical information. Even after the organization of the Mines Section of the Geological Survey, these matters of statistical information and of more direct aid to the mining industries of the country became matters of frequent discussion among mining men and others associated with the industry.

These discussions seem to have culminated in the passing of the following resolution at the Montreal meeting of the newly organized Canadian Mining Institute in 1900:

Resolved that the Canadian Mining Institute in annual session assembled desires to direct the attention of the federal government to the magnitude and importance of our mining industry which during recent years has developed so rapidly and respectfully urges an increase of government aid wherever possible and the establishment of a strong and practical Department of Mines or of a department which

shall be devoted to the interests of the mining and metallurgical industries and which shall include the Geological Survey and all other necessary branches.

This resolution, when presented to the government, was also accompanied by a statement and recommendations with reference to the establishment of the proposed Bureau or Department of Mines, as follows:

It requires an independent head, which, while responsible to a minister, should be practically free from political control, and administered entirely on a non-partisan basis.

Should be divided into three main divisions, viz.,

(1) A Geological Survey,

(2) A Mining and Technical branch,

(3) A Statistical branch.

1. The present survey to be reorganized and the different branches separated so as to avoid confusion; *e. g.*, a Topographical branch, which would greatly expedite the work of another branch, viz., the geological branch proper. There also should be divisions to include petrography, chemistry, palæontology, etc.

2. The mining and technical branch should deal with inspections and reports concerning the economic possibilities of districts already discovered, and of regions yet to be explored. Monographs on various localities, industries, processes and methods should be issued frequently. This branch also should deal with questions of production, transportation and cost. If possible, the head of this division should be an experienced and practical (if not practising) mining engineer.

The difficulty of obtaining such a man leads to the suggestion that the head officer of this bureau should have a list of competent engineers who are authorities in the different fields or branches of the profession, who should be called upon, when required, to report upon special subjects or special operations, at the discretion of the head officer, or when demanded by the public interests.

3. The statistical work is rendered necessary by the different ways and units employed at present by the different provinces of the dominion, and by the fact that existing statistics from any department of the Government are not inclusive of all the information that is available on any one material or subject.

It happened that some years previously, as a result largely of informal discussions and interviews, this question of the establishment of a Department of Mines had already been favorably

considered by a responsible minister of the Crown. We find that a few months after the resolution above quoted was presented to the cabinet, an order in council was passed making a new appointment to the position of superintendent of mines, an office in the Department of the Interior which had been created nearly thirty years previously. The first duty assigned to this officer was the establishment of the Dominion Government Assay Office at Vancouver. In the following six years a number of technical reports on mining subjects were prepared and published under the direction of this officer. The most important work undertaken during this period was probably the investigation of the processes of electric smelting of iron ores in Europe, followed by the experimental work under government auspices in electric smelting of iron ores at Saulte Ste. Marie. Another important innovation was the introduction of the Swedish methods of magnetic surveying for exploring Canadian magnetite deposits, and the publication of a monograph on "Magnetometric Methods of Surveying."

During this period, we find an anomalous state of affairs in the organization of the governmental service for investigating mines and mining. The original Department of the Geological Survey, one branch of which was engaged in special investigations of mining matters, was presided over by the Minister of the Interior. Under this same minister, in the Department of the Interior, was a Technical Branch, controlled by a superintendent of mines, and a third branch, called the Mines Branch,[1] also existed, in which was vested the control of mineral lands belonging to the Crown.

It was not until near the end of the year 1906 that the government decided to further accede to the wishes of those interested in the mining industry, as made known to it both by the resolution of the Canadian Mining Institute, and independently, by individuals and corporations. On the twenty-seventh of April, 1907, the statute now in force, entitled "An Act to Create a Department of Mines" (6–7 Edward VII., Chap. 29), became law. In general principles this Act embodies all the recommenda-

[1] At present, this branch of the Department of the Interior is called "The Mining Lands and Yukon Branch."

tions contained in the resolution of the Canadian Mining Institute, presented to the government six years before.

The principal clauses of this statute are as follows, the numbers being those of the original Act:[1]

1–2. Include merely the short title of the Act and certain definitions.

3. Establishes "The Department of Mines under the control and management of a Minister of Mines."

4. "The department shall administer all laws enacted by the Parliament of Canada relating to mines and mining, and shall also have the management and direction of all subjects assigned to it by the Governor in Council."

. . . . . .

5. "The department shall consist of two branches, one of which shall be called the Mines Branch, and the other of which shall be called the Geological Survey."

6. "The functions of the Mines Branch shall be: (*a*) to collect and publish full statistics of the mineral production and of the mining and metallurgical industries of Canada, and such data regarding the economic minerals of Canada as relate to the processes and activities connected with their utilization, and to collect and preserve all available records of mines and mining works in Canada; (*b*) to make detailed investigations of mining camps and areas containing economic minerals or deposits of other economic substances, for the purpose of determining the mode of occurrence, and the extent and character of the ore-bodies and deposits of the economic minerals or other economic substances; (*c*) to prepare and publish such maps, plans, sections, diagrams, drawings and illustrations as are necessary to elucidate the reports issued by the Mines Branch; (*d*) to make such chemical, mechanical and metallurgical investigations as are found expedient to aid the mining and metallurgical industry of Canada; (*e*) to collect and prepare for exhibition in the Museum specimens of the different ores and

[1] It has not been thought necessary to publish the statute in detail; only those clauses which explicitly define the functions of the various branches of the service and the scope of their investigations are here reproduced.

associated rocks and minerals of Canada and such other materials as are necessary to afford an accurate exhibit of the mining and metallurgical resources and industries of Canada."

7. "The functions of the Geological Survey shall be: (*a*) to make a full and scientific examination and survey of the geological structure and mineralogy of Canada; to collect, classify, and arrange for exhibition in the Victoria Memorial Museum such specimens as are necessary to afford a complete and exact knowledge of the geology, mineralogy, palæontology, ethnology, and fauna and flora of Canada; and to make such chemical and other researches as will best tend to ensure the carrying into effect the objects and purposes of this act; (*b*) to study and report upon the facts relating to water supply for irrigation and for domestic purposes, and to collect and preserve all available records of artesian or other wells; (*c*) to map the forest areas of Canada, and to make and report upon investigations useful to the preservation of the forest resources of Canada; (*d*) to prepare and publish such maps, plans, sections, diagrams and drawings as are necessary to illustrate and elucidate the reports of surveys and investigations; (*e*) to carry on ethnological and palæontological investigations."

8. "The department shall maintain a Museum of Geology and Natural History for the purpose of affording a complete and exact knowledge of the geology, mineralogy and mining resources of Canada."

9. "The Governor in Council may appoint a Deputy Minister, a Director of the Mines Branch, a Director of the Geological Survey, and such other officers and clerks as are required for the proper conduct of the business of the department, who shall be appointed and classified under schedule A of 'The Civil Service Act,' and in accordance with and under the terms of section 6 of the said Act."

10–19. Deal with internal affairs of the department, appointments, restrictions, equipment, and annual summary reports.

20. "The minister may cause distribution to be made of duplicate specimens to scientific, literary and educational institutions

in Canada and other countries, and also authorize the distribution or sale of the publications, maps and other documents issued by the department."

21. "The minister may, for the purpose of obtaining a basis for the representation of the mineral, mining and forestry resources and of the geological features of any part of Canada, cause such measurements, observations, investigations and physiographic, exploratory and reconnaissance surveys to be made as are necessary for or in connection with the preparation of mining, geological and forestry maps, sketches, plans, sections or diagrams."

22. "Chapter 65 of the Revised Statutes, 1906, is repealed."

During previous years, several statutes and amendments thereto had been passed, establishing the Department of the Geological Survey and defining its functions. These various statutes were subsequently consolidated and revised, appearing as Chapter 65 of the Revised Statutes of Canada. Section 22 of The Geology and Mines Act, 1907, specifically repeals these statutes, and section 5 constitutes the Geological Survey Branch of the Department of Mines. The purpose of this change appears to have been to avoid having two deputy ministers administering small departments whose work was closely related, and to avoid a continual overlapping of work, which would lead not only to confusion but to waste of time and effort and loss of efficiency.

A comparison of sections 6 and 7 of the act, quoted above, will show that in general the Mines Branch of the Department of Mines is concerned with technical problems and with the detailed investigation of mining properties, while the more purely scientific and geologic investigations and the exploratory work are assigned to the Geological Survey Branch.

The department is administered by a deputy minister, acting under the Minister of Mines. Directly under the deputy are the editor's branch, with a staff of four, and the accountant's branch, also with a staff of four, neither of which is, however, recognized

as a special branch of the Department of Mines by the statute. The technical work of the department is carried on, under the administrative head, by the two principal branches of the department, the Mines Branch and the Geological Survey Branch. The work of each of these branches is controlled by principal technical officers, who are termed respectively the Director of the Mines Branch, and the Director of the Geological Survey Branch.

The Mines Branch.

The Mines Branch, as at present constituted, is divided into the outside and inside service, both services being under the Director of the Mines Branch. The Dominion Government Assay Office at Vancouver is attached to the outside service; the inside service, with headquarters at Ottawa, is organized for administrative purposes into the following divisions: Metal Mines Division, Non-metal Mines Division, Fuel and Fuel Testing Division, Chemical Division, Mineral Resources and Statistics Division.

It has recently been publicly announced by the Minister of Mines that it is the intention of the government to introduce at the next session of Parliament an act providing for the regulation of the manufacture, storage and testing of explosives in Canada. For the purpose of carrying out the provisions of this act, an Explosives Division of the Mines Branch is to be established and an explosives testing station is to be erected and maintained.

Outside Service.—The Dominion Government Assay Office at Vancouver was established at that point to purchase and market gold from the Yukon, British Columbia and the adjacent provinces. The staff of the assay office consists of one manager, two assayers, two melters, one clerk, and one caretaker, a total of seven.

Inside Service.—The inside service of the Mines Branch has its headquarters in Ottawa. Without going into details, it may be stated that the energies of the technical officers of the Mines Branch staff, at the present time, are being concentrated along several distinct lines of work, as follows:

1. The preparation of a series of special monographs describing the natural resources of the country with respect to certain minerals or ores, and discussing the latest and most economical methods of utilizing these resources and of marketing the products.

2. Special investigations of special processes which may be of value to some of the many mining and kindred industries of Canada, or which may lead to the development of other industries.

3. Investigation of the economical utilization of the fuel resources of the country.

4. Collection, compilation, publication and distribution of detailed statistical information with respect to the mining and related industries of Canada.

5. Special investigations into the manufacture, storage, transportation and use of explosives in Canada, for the purpose of suggesting measures which it is hoped will tend to reduce the large number of accidents due to explosives.

6. Conduct of such chemical investigations as are necessary to supplement the investigations of the officers of either branch of the department. In addition, the Chemical Division of the Department of Mines does a large amount of analytical work for private individuals, at commercial rates. This work is such that the division is almost self supporting, but, at the same time, it rather seriously interferes with the legitimate work of the division.

The total number of employees now on the inside staff of the Mines Branch, when all existing vacancies are filled, will be twenty-four, besides three technical officers and several laborers not on the permanent organization.

The Geological Survey Branch.

The Geological Survey Branch of the Department of Mines, working under the control of the Director of the Geological Survey, is organized as follows: administrative and general division; geological division; palaeontological division; mineralogical

division; topographical division; natural history division; draughting division; library.

At the present time, the work of collecting and caring for material for the new Victoria Museum is also carried on by special officers of the Geological Survey Branch.

In the work of this branch of the Department of Mines each principal field officer usually has his own special field of investigation. He organizes his own field party, and such assistants as as are required, or can be obtained, are assigned to him, either from the junior officers of the staff or from a special staff of student assistants, temporarily engaged for that purpose. Usually, he has also to carry out his own topographical surveys. In the more important fields the topographical work is performed under the direction of a special topographer.

The staff of the topographical division of the Geological Survey is very small, too small for the work that has to be done, and it is only rarely that the topographic work can precede the geologic. At the present time, their work is confined to some of the more important mining districts, where an officer of this section of the survey takes charge of the topographic work, while the geological work is carried on by a geologist. A large number of student assistants are usually employed on this service during the summer months.

It has already been announced that during the present season the Geological Survey Branch will have twenty-two geologic parties and three topographic parties in the field, the parties being distributed through all the provinces of the Dominion. Difficulty is being experienced in obtaining men to take charge of additional investigations which are planned, though it is hoped that several other field parties will be organized.

The total number of employees on the permanent staff of the Geological Survey Branch, when all existing vacancies are filled, will be seventy-four. This does not include a number of temporary employees at Ottawa. It is customary to engage the services of a number of independent geologists, usually members of the geological staff of some university, for the summer months

for special investigations. Field assistants and camp employees, whose numbers vary from year to year, are not included on the permanent staff of the branch.

Conclusion.

During recent years, the value of the mineral output of Canada has been increasing very rapidly. For the year 1909 the preliminary estimate made by the chief of the Division of Mineral Resources and Statistics places this value at $90,415,763, being second only in value to the products of agriculture.

The funds voted by Parliament for the service of what is now the Department of Mines have usually been very small, being little over $100,000. It is only within the last few years that there has been any notable increase; for 1909–10 the total amount available was $505,187.50, being slightly more than one half of one per cent. of the annual value of the industry for the same year. For the fiscal year 1910–11 the total vote at the service of the department for all purposes is $621,289, the largest since the organization of the Department of Mines, or of its predecessor, the Geological Survey. This amount includes a special grant for the investigation of processes for producing zinc. The amount apportioned to the Mines Branch is $207,762.50, and to the Geological Survey $369,289.

STRATIGRAPHIC RELATIONS OF THE LIVINGSTON FORMATION OF MONTANA.

PART II.

R. W. STONE AND W. R. CALVERT.

AREA BETWEEN BOULDER RIVER AND BRIDGER RANGE.

Between Stillwater and Boulder rivers there is an area where highly accidented topography is the rule, due to the occurrence of the agglomerate member of the Livingston as the surface rock. This area was not examined in 1908 and the exact distribution of the Livingston and associated formations is therefore not known. It is believed, however, that the Beartooth fault is continuous across this unmapped area and that the agglomerate is thus terminated abruptly on the south.

On Boulder River the entire Mesozoic section is well exposed, and it was in this locality that the first opportunity presented itself to study that part below the coal-bearing sandstone previously classed as "Laramie." Underlying this sandstone is a thick mass of shale and sandstone which had been separated by Weed into the Colorado and Montana groups, about half of the total thickness being assigned to each. The assertion had been made that it was very difficult to differentiate these beds on lithologic grounds and that practically no fossils had been collected from the upper members. This difficulty in separation was amply borne out in the work of 1908 and the discovery of Colorado fossils 300 feet below the lowest coal zone of the "Laramie" demonstrated that the rocks represented a paleontologic as well as a lithologic unit. Stanton and Calvert made a collection of fossils at the base of a bluff near the southwest corner of T. 2 S., R. 13 E., in which Stanton determined the following forms:

Ostrea sp.

Avicula sp. Related to *A. gastrodes* Meek.

Inoceramus sp. Fragments of a thick-shelled type like *I. deformis* and others of the Colorado group.
Nucula sp.
Leda sp.
Fusus? undescribed.
Placenticeras sp.
Scaphites ventricosus M. & H.
Scaphites vermiformis M. & H.
Baculites asper Morton?

In commenting on the preceding list Stanton writes as follows:

> The determination that these fossils are Colorado is dependent chiefly on the last three species of the list. These are all ammonoids that are known only from a horizon near the top of the Colorado shale where two of them have been found at many localities in Montana and the third—that is *Scaphites vermiformis*—though rare occurs at the same horizon. The query after *Baculites asper* refers to its identification with Morton's original type, which came from another region. There is no doubt about the identity of the species collected here with a common form in the Colorado of the state of Montana.

Since this collection was made from a horizon 300 feet beneath the lowest coal and the beds immediately above evidently belong to the same formation and were found to grade upward into the coal-bearing sandstone, doubt was cast at once on the propriety of considering this sandstone as "Laramie," because there is no room in the section for the thick and paleontologically distinct Montana group which should appear in conformable sequence between the Colorado and the "Laramie."

Still more suspicion was raised relative to the stratigraphic relations of these beds by conditions found in sec. 1, T. 3 S., R. 13 E., where the agglomerate member of the Livingston formation is shown on the Livingston folio as unconformable on lower beds down to the Colorado as defined by Weed. In his description of the agglomerate Weed states that, "A careful examination shows at a number of localities a decided unconformity between the beds at the top of the series (leaf beds) and the overlying agglomerates." In the Livingston folio, however, only one locality of unconformity is mapped. This area was

examined by Stanton, Kay and Calvert and the opinion was unanimous that the structure had been misinterpreted, for instead of an unconformity of considerable magnitude as mapped in the folio, there is an unmistakable fault, as shown on the accompanying map. Since no unconformity exists here and the "Laramie" is transitional into the Livingston here as elsewhere, there seemed additional reason to doubt the correctness of the previous conclusions reached in the Livingston region relative to the stratigraphy.

Two other collections were made from beds below the "Laramie" and will be mentioned here as evidence that the consideration of the entire mass of shale and sandstone underlying the coal-bearing measures as Colorado rests on a reasonable basis. One lot was collected on a ridge between the forks of Trail Creek outside the area shown on the map, from rocks which had been traced continuously from the district southwest of Livingston. The horizon is very near the top of beds previously considered Montana and the collection contained the following forms:

Ostrea sp.
Exogyra sp.
Inoceramus sp.
Pinna sp.
Crassatellites sp.
Turritella sp.
Gyrodes sp.
Fasciolaria? sp.
Acteon sp.

These are assigned by Stanton without comment to the upper Colorado.

Still farther without the area shown on the map is another locality where collections were made which have a direct bearing on the age of the rocks previously assigned to the Montana. This is in the vicinity of Electric, near the north entrance to Yellowstone Park. A small coal field occurs here which Calvert examined in 1908. In the Livingston folio the coal-bearing sandstone at Electric is correlated with the coal measures near Livingston and the underlying rocks are assigned to the Montana. Plants have been cited from these sandstones at Electric which are similar to those from the coal measures of the Livingston area and since the stratigraphy is likewise very similar there

seems every reason for the correlation. Just beneath the coal-bearing sandstone the following forms were collected:

Ostrea sp.
Inoceramus acuteplicatus Stanton.
Baculites asper Morton?
Scaphites ventricosus M. & H.

These also are assigned by Stanton to the upper Colorado.

That all the beds in the Livingston section between Weed's "Dakota" and the coal-bearing sandstone assigned by him to the "Laramie" are Colorado, is therefore confidently asserted.

From the coal-bearing sandstone in the vicinity of Livingston only a few invertebrates have been obtained. Stanton made one collection in the SE¼, sec. 26, T. 2 S., R. 11 E., concerning which he states that

> "This lot contains a number of obscure casts of bivalve shells which, on account of their lack of definite characters, have not been identified even generically. Their general forms, however, indicate that they belong to two or more *marine* genera and that they are therefore probably older than the Laramie."

From the correlated sandstone at Electric, however, more definite evidence has been obtained. Mr. Robert M. Magraw, superintendent for the Montana Coal and Coke Company, at Electric, forwarded to T. W. Stanton several collections from the coal measures. One is from the Newton mine, 80 feet stratigraphically above No. 3 coal bed and includes the following:

Modiola sp., fragments of a striated species.
Cardium sp., probably new.
Corbula perundata M. & H.
Fusus? sp.

From strata in the Foster mine a single small specimen was taken resembling the young of *Corbicula occidentalis* M. & H. Stanton, who made the identification, writes as follows concerning these collections:

> These fossils include both brackish water and marine species. The brackish water forms are the *Modiola* and the *Corbula*, both of which have been found in the Judith River and Claggett formations of other parts of Montana and in the Mesaverde of Wyoming and Colorado.

The *Corbicula* belongs to the same fauna and has about the same range, though similar species occur in the Laramie also. The *Cardium* and the *Fusus,* although not specifically determined, are especially important because they are marine forms and are therefore strong presumptive evidence that the rocks from which they came are older than Laramie. Taken together, therefore, the fossils tend strongly to confirm the opinion previously reached on the basis of stratigraphic evidence that the coal-bearing rocks at Electric belong in the Montana group and are older than Laramie.

A third collection sent in by Mr. Magraw from the coal measures at Electric, included the following as identified by Stanton:

Ostrea subtrigonalis M. & H.
Corbula sp.
Melania insculpta Meek.
Melania sp.

In a letter to Mr. Magraw, Stanton writes:

These species are in part different from those which you sent last spring from a neighboring locality, but they belong to the same general fauna and tend to confirm the conclusion then reached—that your coal-bearing formation is older than Laramie.

Invertebrate evidence, therefore, as well as stratigraphy, indicates that the coal measures of the Livingston section are of lower Montana age instead of Laramie as previously supposed. As Weed has pointed out, the beds which he assigned to the "Laramie" rest conformably on those which he assigns to the "Montana" (upper Colorado of this paper), and there is every appearance of perfect transition from the lower into the higher formation. His conclusions are as follows:

The perfect stratigraphic continuity of the marine Cretaceous with the Laramie is apparent everywhere. No break occurs, and no evidences of unconformity have been observed up to the top of the formation.

Weed's assertion that the "Laramie" sandstone is *prevailingly* made up of Archean detritus and the Livingston of andesitic material is conceded, but his other statement that there is a sharp lithologic distinction between the "Laramie" and the overlying Livingston is not granted. The zone along the line of contact between "Laramie" and Livingston was noted carefully

throughout the Livingston area and instead of unconformity there seems to be every indication of a transition from one to the other formation. The transitional zone is sometimes narrow, it is true, but in no locality were beds *wholly andesitic* found to rest on rocks *wholly of Archean material.* This fact seems to explain the different thicknesses assigned by Weed to the "Laramie," as he undoubtedly measured from the top of beds which he considered Montana up to the first appearance of andesitic material. Since, however, andesite is not always to be found at the same horizon, it follows that there appears to be a variation in the thickness of beds considered "Laramie."

From Boulder River the coal measures and associated formations were followed westward along their strike to the Bridger Range except for a short interval near the east border of T. 2 S., R. 6 E., where the Neocene lake beds of Gallatin Valley overlap rocks up to the lower portion of the Livingston formation. The agglomerate, which is so prominent on the Boulder becomes thinner to the west, and disappears shortly after crossing Yellowstone River. At Livingston the section shows about 800 feet of coal measures, underlain by about 3,700 feet of Colorado shale, as measured below Yellowstone Canyon. Above the coal measures is a great thickness (at least 5,000 feet) of andesitic or tuffaceous sandstone and shale constituting the Livingston formation. The section has been described by Weed in considerable detail, however, and a repetition does not seem essential here.

AREA EAST OF THE BRIDGER RANGE.

Structurally, the Bridger Range is an anticline, overturned to the east. The western slope is relatively gentle, while the range is quite impressive as viewed from the east. Along the eastern base the rock section, though largely concealed by dense timber, was found to be similar in nearly every detail to that at Livingston. At Bridger Creek, which cuts the southern end of the range, exposures are good, showing the Colorado, the coal measures, and andesitic beds standing vertical or dipping at a high angle to the east. From this locality the coal-bearing sandstone

can be followed continuously northward, except for very short intervals, to Brackett Creek, whose erosion has bared more of the rocks than usual on the east flank of the Bridger Range. At Brackett Creek the section is entirely comparable to that at Livingston, consisting of (1) a mass of shale and sandstone corresponding to the Colorado and "Montana" of the Livingston section, as described by Weed in the Livingston folio, but which are now considered to be wholly of Colorado age; (2) a coal-bearing sandstone yielding plants identical with those from the coal measures at Livingston, and (3) typical andesitic material carrying a Livingston flora.

One notable difference, however, is found at a horizon well up in the andesitic beds, where a heavy conglomerate, described by Weed as the upper member of the Livingston, appears. Considerable importance is attached by Weed to this conglomerate, and in order to facilitate discussion the following quotation is given from his report:[1]

> The importance which attaches to these conglomerates arises from the light they throw upon the relation of the Livingston formation to the Laramie and to the post-Laramie movements which elsewhere have been found to be so important. The large size of the pebbles of the conglomerate permits a ready recognition of their lithological nature and this, upon examination, proves to be of the greatest interest. In the cliffs east of Bridger Creek and the ridges cut by Brackett Creek, the conglomerates of the series occupy a very prominent part of the formation. . . . Sections made near Stones Creek and on Brackett Creek show a thickness of 2,000 feet of very coarse sandstones and conglomerates in which a large number of pebbles are noted that are not of volcanic origin. In both these sections the conglomerates contain pebbles of granite, quartzite of various colors, limestones showing chert and Carboniferous fossils, and Cretaceous shale and sandstones.

No special study of this conglomerate was made by Calvert in the field in order to ascertain its relation to the underlying beds. Casual observation, however, confirmed Weed's statements regarding the lithology of the pebbles. That the varied character of these pebbles argues for an unconformity is admitted, but why that unconformity should be placed at the base of the ande-

[1] W. H. Weed, "Laramie and Livingston Formation in Montana," Bull U. S. Geol. Survey, No. 105, p. 31.

sitic beds constituting the Livingston formation is not clear, for between the conglomerate and the coal measures is a great thickness of andesitic rocks of fairly uniform composition. The facts seem much more in accord with Weed's additional statement that "There is some evidence that may prove sufficient cause for a separation of these conglomerates and silts from the Livingston formation and their recognition as the base of the Fort Union group."

The conglomerate, developed so markedly on Brackett Creek, thins out either way along the strike, and in Shields River Valley near Myersburg is no longer recognizable. It seems probable, however, that the conglomerate occupies about the same stratigraphic position as the light-colored sandstone near Clyde-park which on the evidence of fossil plants is Fort Union.

From Brackett Creek northward exposures of the rocks below Livingston beds are rare, owing to extremely dense timber or talus material along the base of the Bridger Range. An attempt was made in 1909 to follow the coal measures north continuously to the vicinity of Flathead Pass and thence northeastward to the locality where Stone had discontinued mapping in 1907, but the best that could be done was to make fossil collections and to observe the stratigraphic succession wherever opportunity afforded. One such locality was found in the north central part of T. 3 S., R. 6 E., near the wagon road from Flathead Valley to Fleming. On the east side of the road the rocks dip to the south at a considerable angle and exposures, though not continuous across the section, give a fair idea of the stratigraphy. Typical Colorado shale merges upward into sandstone mapped as "Laramie" in the Little Belt Mountains folio, and this in turn is overlain by the typical brown or green andesitic sandstone of the Livingston. Fossils were collected by Stanton, Campbell and the writers from beds at the base of the coal measures. These have been identified by Stanton and contain the following forms:

Ostrea sp.
Anomia sp.
Nucula sp.
Crassatellites sp.
Tellina sp.
Legumen sp.

This horizon is the same as that to the east of Blair's ranch, from which a larger collection of fossils was made which Stanton referred to the Eagle fauna.

Eastward from the locality mentioned the beds were not followed continuously by the party in 1909, but they were again studied near Blair's ranch, in sec. 24, T. 4 N., R. 7 E. The stratigraphy here is very similar to that of the locality discussed in the preceding paragraph. The same fossil horizon was found at the base of the coal measures, a carbonaceous zone was found near the top of the sandstone member, and this sandstone was found to be overlain by typical andesitic material. From the base of the coal measures the following fossils were obtained.

Ostrea sp.
Avicula sp.
Leda sp.
Crassatellites sp.
Protocardia? sp.
Tellina sp.
Baculites sp.
Scaphites sp.

These are marine Cretaceous fossils and are referred by Stanton to a lower Montana fauna. The horizon was mapped as Eagle by Stone on account of its stratigraphic position and lithologic character. In this connection it should be stated that both the fauna and the flora of the Eagle sandstone are meager and imperfectly known in the typical area of the formation on the Missouri River below Fort Benton. This is also true in other areas, where the Eagle sandstone has been identified chiefly by its lithologic character and by its stratigraphic position immediately above the Colorado shale.

The determination of the age of the coal-bearing sandstone at Blair's ranch as Eagle is confirmed further by the collection of a good upper Colorado fauna about 300 feet below its base. This collection, made one mile northeast of Blair's house in sec. 24, T. 4 N., R. 7 E., is as follows:

Serpula sp.
Ostrea sp.
Avicula gastrodes Meek.
Inoceramus exogyroides Meek.
Inoceramus sp.
Pholadomya papyracea M. & H.
Gyrodes sp.
Turritella sp.
Baculites asper Morton?
Prionotropis sp.

One difference between the lithology of the foregoing section and that at Livingston was noted. In the latter locality andesitic material is found rarely in the coal measures, and none in the Colorado. At Blair's ranch, however, there are prominent andesitic members in the coal measures, and similar material was found 300 feet below the fossil horizon near the base of the Eagle sandstone. This was the first instance noted of the occurrence of andesitic material so low in the stratigraphic column. The recurrence of volcanic material at various horizons becomes more and more noticeable to the northeast, as will be brought out in the succeeding chapters. It may be remarked in passing that the lithology of the beds above the coal measures near Blair's ranch is strikingly similar to that of the area northwest of Red Lodge, where the section given in a preceding chapter (Red Lodge-Nye District) was made.

AREA WEST OF THE CRAZY MOUNTAINS.

The area west, north and northeast of the Crazy Mountains was studied by Stone in 1907. He was assisted in the field by M. I. Goldman, and during the field season had material aid from visits by C. A. Fisher, F. H. Knowlton, A. C. Peale and T. W. Stanton. Work was begun near Shawmut in range 17 and carried westward to the head of the south fork of Musselshell River, and thence southward to Clydepark.

At the outset of this part of the discussion it is necessary to call attention to the formations described by Weed. In the Little Belt Mountains folio[1] Weed divides the rocks of post-Jurassic age into four formations, called Yellowstone, Laramie, Livingston and Fort Union. His Yellowstone formation is described as having an unconformity at its base and consisting of the Dakota, Colorado and Montana formations, largely shale with interbedded sandstone, and for the most part containing marine fossils. His "Laramie" formation is described as light gray or yellow sandstone with shale beds and workable seams of coal. It carries plant remains and brackish water shells.

[1] Little Belt Mountains folio (No. 56), Geologic Atlas U. S. Geol. Survey, 1895.

The thickness of these beds is given as about 1,000 feet. In his geologic column Weed shows the "Laramie" as terminated by an unconformity, above which is about 7,000 feet of dark brown and green sandstone, in places tuffaceous and conglomeratic, and great thicknesses of tuffaceous shale with thin beds of limestone; also local intercalations of breccias and agglomerates representing volcanic eruptions. He called these dark-colored tuffaceous beds the Livingston formation.

Resting conformably on these somber-hued beds is the Fort Union formation. It is over 4,000 feet thick and consists of light gray and yellow friable sandstone, massive and cross-bedded, alternating with gray clay shales with occasional lenticular impure limestone and hard sandstone.

This considerable thickness of Cretaceous sediments on the north and east of the Crazy Mountains has been further subdivided within the past few years. In 1902 Douglass[1] recognized a fresh and brackish water formation under the name "Fish Creek beds" and correlated it with the Belly River of Canada. The sandstones beneath he referred to the "Niobrara," under which term he evidently included the strata now referred to Eagle and Claggett. He recognized as Pierre the shale now called Bearpaw, and called the dark-colored ridge-making sandstone above it Fox Hills. It seems probable that all the formations except the Benton discussed by Douglass lie above Weed's Yellowstone formation.

In 1903 the work of Hatcher and Stanton[2] on Missouri River and elsewhere in northern Montana established the following stratigraphic sequence in strata which they considered the equivalent of the Pierre shale:

Bearpaw,	Claggett,
Judith River,	Eagle.

[1] Earl Douglass, "A Cretaceous and Lower Tertiary Section in South-Central Montana," *Proc. Am. Phil. Soc.*, Vol. XLI., 1902, pp. 207–224. "A Geological Reconnaissance in North Dakota, Montana, and Idaho, with Notes on Mesozoic and Cenozoic Geology," *Annals Carnegie Mus.*, Vol. V., 1909, pp. 266–278.

[2] Hatcher & Stanton, "The Stratigraphic Position of the Judith River Beds and their Correlation with the Belly River Beds," *Science*, n. s., Vol. XVIII., pp. 211–212.

Their field work of that season was extended to the Fish Creek area south of Shawmut in range 17 where they recognized all of these formations,[1] the Bearpaw being identified by means of its fauna of marine invertebrates, the Judith River by its vertebrates, lithology and stratigraphic position, and the other two by stratigraphic position and lithology. It was found that Douglass' "Fish Creek beds" are the Judith River formation.

The Cretaceous succession as measured by Stone in the Musselshell Valley southeast of Harlowton is as follows:

	Feet.
Montana group:	
Bearpaw shale	700–1,100
Judith River formation	400– 800
Claggett formation	400– 800
Eagle sandstone	100– 250
Colorado shale	1,300
Kootenai formation	250
Morrison formation	150

Weed's Yellowstone formation, to the best of our knowledge, probably includes the Morrison, Kootenai and Colorado formations. As to what he actually called "Laramie" in the field north and northeast of the Crazy Mountains there are several lines of evidence.

1. His mapping of the "Laramie" in the Little Belt Mountains folio corresponds in a general way with Stone's mapping of the Eagle sandstone.

2. He records[2] brackish-water shell remains occurring "interbedded with the Livingston sandstones and conglomerates, a few hundred feet above the base of the formation." The field label accompanying these fossils says, "E. bank of Muddy Creek W. of Gordon Butte and Cottonwood Creek," and very probably is a shell locality found by Stanton and Stone in the upper part of the Claggett at that place. It shows what Weed considered the base of the Livingston on Muddy Creek for the white sandstone of the Eagle is not far below this fossiliferous limestone.

[1] Stanton, Hatcher and Knowlton, "Geology and Paleontology of the Judith River Beds," Bull. U. S. Geol. Survey, No. 257, 1905, pp. 59–60.

[2] W. H. Weed, "The Laramie and the Overlying Livingston Formation in Montana," Bull. U. S. Geol. Survey, 1893, No. 105, p. 33.

3. Weed's very generalized section of the rocks on Lebo Creek published[1] in 1896, taken in connection with his mapping there and in comparison with Fisher's section in the same neighborhood, indicates that his "Laramie" on Lebo Creek probably includes the Eagle and all or part of the Claggett. In both the sections mentioned the Bearpaw and Judith River are poorly exposed and were most likely included in the Livingston without study.

With this explanation of the formations on the north and east of the Crazy Mountains as described both by Weed and Stone, we will proceed with a description of the details bearing on the Livingston problem as found on the west side of the Crazy Mountains.

In the Livingston and Little Belt Mountains folios[2] Weed shows the valleys of Sixteenmile Creek, Shields River and Potter Creek underlain by the Livingston formation. In both folios the description is as follows:

> The formation consists of a great thickness of conglomerates, sandstones and clays with local intercalations of volcanic agglomerates and breccias. The rocks rest upon the white sandstone of the Laramie coal measures from which the lower beds of this series are readily distinguishable by their somber color. . . . The fossils of the Livingston formation do not yet afford conclusive evidence of its age. It is most nearly allied with the upper Cretaceous, but is separated from the Laramie by an unconformity and a period of volcanic activity with mountain development.

Late in the summer of 1907 Stone made a rapid examination of a single range of townships west of the Crazy Mountains, extending from the head of the Musselshell to Clydepark. Having traced the Eagle sandstone continuously for many miles up the Musselshell there was no question as to its identity on Sixteenmile Creek, where it is exposed on both sides of the valley. The Fort Union beds were recognized at Shields and Clydepark. Between these and the Eagle sandstone there is,

[1] W. H. Weed, "The Fort Union Formation," *American Geologist*, 1896, p. 206.

[2] Livingston Folio (No. 1), Little Belt Mountains Folio (No. 56), Geologic Atlas U. S. Geol. Survey, 1894, 1895.

however, a mass of sedimentary rocks several thousand feet thick which on lithologic grounds must be classed as a unit or single formation. It may be described as consisting of sandstone and shale, for the most part dark colored, and frequently tuffaceous in character or intercalated with many beds of tuff. Fossil horizons as yet discovered are few.

Practically the only fossils discovered in Potter Creek valley between the Eagle and Fort Union are of upper Montana age. These are all marine shells from sec. 25, T. 4 N., R. 8 E., on a ridge road four miles north of Myersburg and between 2,500 and 3,000 feet above the base of Weed's Livingston. The list is as follows:

SHELLS FROM LIVINGSTON FORMATION NORTH OF MYERSBURG.
(Coll. No. 6029.)

Ostrea sp.	*Siliqua?* sp.
Avicula nebrascana E. & S.	*Corbula* sp.
Limopsis parvula M. & H.?	*Thracia* sp.
Nucula sp.	*Mactra* sp.
Tancredia americana M. & H.	*Lunatia* sp.
Callista sp.	*Lelania?* sp.
Tellina sp.	*Scaphites nodosus* Owen.

Of this collection Stanton says:

> Although many of the forms in this lot are not well enough preserved for specific identification those that are identified and the general characters of the other show the fauna is marine and that it is late Cretaceous. Its horizon is probably near the top of the Bearpaw.

This collection comes from near the top of a sandy formation which is overlain by a shaly mass of considerable thickness. The sandstone carrying the shells is greenish, mottled with small brown spots. It is the same horizon as that traversed by the ridge road for several miles south of Dorsey. The fact that marine shells of late Cretaceous age occur well up in the Livingston formation as mapped by Weed is the point to which attention is called.

Three miles northeast of this locality and several hundred feet

above the Eagle sandstone in T. 4 N., R. 8 E., sec. 12, Stone collected a single specimen of *Cunninghamites elegans* (Corda) Endl. which Knowlton considers indicative of Judith River. Two or three miles farther north in T. 5 N., R. 8 E., sec. 23–25, *Phyllites denticularus?* Kn., *Populus cretacea?* Knowlton, and fragments of dicotyledons were found about 1,600 feet above the Eagle; and still farther north in sec. 14 of the same township at about 1,277 feet above the Eagle, Goldman found *Cunninghamites pulchellus* Knowlton and *Sequoia reichenbachi* (Gein.) Heer, which Knowlton considers probably of Judith River age, although the latter form is common in the typical Livingston flora.

In a canyon three miles east of Dorsey and one eighth mile above the new grade of the C. M. & P. S. Railroad, in sec. 22, T. 7 N., R. 8 E., fossil shells and leaves were collected in typical Livingston beds within a vertical range of less than 20 feet and stratigraphically from 400 to 500 feet above a white sandstone mapped by Stone as Eagle. These fossils are of Judith River age. A list of the genera from Stone's collections No. 611–612 and Stanton's No. 1478 follows:

Sphærium sp.
Physa sp.
Campeloma? sp.
Limnæa? sp.
Goniobasis? sp.

Concerning these invertebrates Stanton says: "This freshwater fauna contains no known characteristic species. It may be as old as Judith River."

In beds 10 to 15 feet below the shells three collections of leaves have been found to contain the following species:

Sequoia reichenbachi (Gein.) Heer.
Platanus? sp.
Populus cretacea Heer.
Viburnum? sp. new?
Cinnamonum? sp. new.
Sabalites sp. Same as that found in Judith River at Billings.
Cyperacites sp.
Populus sp.?

A number of fairly well preserved small leaves which appear to be new to science.

Knowlton considers this a Judith River flora, and the determination is substantiated by a collection of leaves obtained about one half mile farther south along the same ridge and in beds at practically the same horizon. This collection is from a ravine one eighth mile northeast of the southwest corner of sec. 23, T. 7 N., R. 8 E., and has been described by Knowlton as follows:

Cyperacites sp.
Geonomites cf. *G. tenuirachis* Lesq.
Populus cretacea Knowlton.
Phyllites sp.

This material is given on the field label as Claggett?, and it may be, but I know as yet no flora from this horizon. Palms have not before been reported from this part of the section in Montana. *Geonomites tenuirachis* was described originally from Raton Mts., N. M., in beds then suposed to be of Laramie age, but which I now incline to regard as Montana. *Populus cretacea* is a Judith River species. I should think it probable that this collection is more likely to be Judith River.

This collection of leaves and the leaves and shells just described from sec. 22 occur stratigraphically from 400 to 500 feet above the Eagle sandstone in Weed's Livingston. Although no fossils were found in the Eagle at this point, the occurrence of *Inoceramus labiatus* Schlotheim below the Eagle is convincing evidence of the Colorado age of the underlying shale.

In sec. 9, T. 7 N., R. 8 E., in beds several hundred feet above the Eagle sandstone *Sequoia reichenbachi* (Gein.) Heer, and *Dammara* sp.? were collected. Knowlton says the age of the beds cannot be determined definitely from these two leaves, but presumably is Judith River.

Limy nodules resembling those found in the Bearpaw shale were seen in the northern central part of T. 4 N., R. 8 E., but so far as discovered they are non-fossiliferous. It seems to the writers that the evidence from Bearpaw fauna and Judith River fauna and flora is sufficient to prove the Montana age of the lower third, at least, of the tuffaceous beds west of the Crazy Mountains which were described and mapped by Weed as the Livingston formation.

The tuffaceous character of the material above the Eagle sandstone in Potter Creek valley on the west side of the Crazy Mountains is proven by the composition of thin sections cut from specimens collected by Stone. These sections were examined by Calkins, Cross, Johannsen and Stone, with the following determinations:

C.M. 13. Andesite tuff. From about the horizon of the Bearpaw shale one-half mile west of Summit. Consists of sharply angular to subangular grains, the most abundant of which are chiefly plagioclase feldspar. Also many fragments of lava with andesitic texture. In smaller amount the section consists of feldsitic rock, pyroxene and masses of iddingsite (?), possibly derived from hypersthene. There are possibly a few grains of alkali feldspar. Quartz was not identified. All the material might belong to a pyroxene andesite tuff.

C.M. 19. Andesite tuff. About 475 feet above the Eagle coal bed, in T. 5 N., R. 8 E., sec. 24. Consists of angular to somewhat rounded grains, chiefly of feldspar and highly altered volcanic rocks, which seems to be andesite, in part vesicular; also something like devitrified glass. No pyroxene or primary quartz was identified. The material is all volcanic and possibly is more worked over and more acidic than C.M. 13 and 15.

C.M. 20. Tuff. About 515 feet above the Eagle coal bed, in T. 5 N., R. 8 E., sec. 24. Consists of a few laths of biotite and plagioclase in a gray glass groundmass. The glass is in small angular particles, having a subangular arrangement. The rock may be a rhyolite tuff or a vitrophyre.

C.M. 21. Tuff. Collected 1,570 feet above the Eagle coal bed in T. 5 N., R. 8 E., sec. 24. The rock is a fine-grained, greenish-brown mass, largely of feldspar and augite, and probably an andesite tuff.

C.M. 22. Andesite tuff. Collected 1,720 feet above the Eagle coal bed, in T. 5 N., R. 8 E., sec. 24. Consists of fragments of plagioclase, hornblende, augite, with abundant magnetite and little or no quartz. It is distinctly a hornblende andesite tuff of coarse granular texture.

C.M. 23. Tuff. 1,730 feet above the Eagle coal bed, in T. 5 N., R. 8 E., sec. 24. Consists of angular to subangular grains of cloudy feldspar and augite, quartz and andesitic lava.

C.M. 24. Tuff. 3,350 feet above the Eagle coal bed, in T. 5 N., R. 8 E., sec. 24. Consists of angular grains of feldspar, lava, augite, quartz and a little hornblende, all of which might be volcanic.

C.M. 26. Andesite porphyry and breccia. From the horizon of the

Claggett formation, one fourth mile northeast of Dorsey. This is a porphyritic rock consisting of many plagioclase laths, some augite, magnetite, and a decomposed ferro-magnesian mineral, which was originally biotite or hornblende. The groundmass consists of a confused aggregate of fine lath-shaped feldspars; apparently it is a massive rock.

These specimens which are distributed through 3,000 feet of material represent the rocks of decided tuffaceous appearance, and the descriptions given are offered as evidence of the volcanic origin of a considerable part of the material composing the thousands of feet of sediments lying between the Eagle and Fort Union formations on the west side of the Crazy Mountains.

(To be continued.)

EDITORIAL[1]

SPECIAL PROBLEMS AND THEIR STUDY IN ECONOMIC GEOLOGY.

SINCE the publication by Mr. S. F. Emmons in 1886 of the monograph on Leadville, Colo., the progress of economic geology in the United States has been phenomenally rapid. So much is this true that this country now admittedly leads all others in the extent, completeness of detail and accuracy of its descriptive reports on mining districts and, what is far more important, in the widespread recognition of practical utility which has been accorded to geological work by men in the mining engineering profession.

This advance has been brought about by a number of conditions, chief among which are perhaps the variety and comparative simplicity of the genetic relations of the majority of our unmetamorphosed western ore deposits, the industry and skill of the men who have conducted the researches upon which published work has been based, and most of all the vigorous lead taken by our federal geological survey with its able corps of trained men in the prosecution of research and in the publication of its careful and extremely valuable bulletins.

Reports have been issued by this survey on nearly all of the larger mining districts of the west, of which those on Cripple Creek, Tonopah, Goldfield, Bisbee, Georgetown and many others are examples, and these have been of immense service to those engaged in the practice of mining and have added greatly to the sum total of geologic knowledge. Still more have the general papers which have from time to time appeared in the Transactions of the American Institute of Mining Engineers, in technical journals and in the transactions of scientific societies contributed to the clearer understanding of important problems of ore dep-

[1] The signed editorials which it is designed to publish from time to time in these columns are expressions of individual views and do not represent the consensus of opinion of the editorial board.

osition, such as that of secondary sulphide enrichment, contact metamorphism, etc. Taken together the work which has been done in this country in the last thirty years undoubtedly forms a monument to which American workers may point with just pride.

In moments of self congratulation, however, over what has already been accomplished, it is not difficult to overlook what may soon become a serious defect in our present method of geologic investigation. The large number of published reports which is gradually swelling the volume of geologic literature, if it does not carry an actual menace of eventual unwieldiness and consequent inutility, is at least suggestive of the need of a method of research and publication which will in some way accelerate the understanding of those fundamental problems of ore deposition which are urgently in need of solution.

That there is the need of some added method of research in the work of our federal survey, our state surveys and even in our universities cannot but be apparent if we carefully examine what has been done. That there *is* such a method and that it may with very little effort be made to supplement those methods now in use is firmly the belief of the writer, and it is the object of these paragraphs to urge its adoption.

There are two radically different methods which may be applied in the study of ore deposits, each of which plays an important part in the progress of the science and in the effectiveness with which valuable results are rendered available to practical men. One of them has been extensively applied in this country —the other little if at all, and then not as the result of any settled policy.

The first may be termed the descriptive geographic method; the second the method of special problems.

The method by districts consists in the complete study of a given geographic area. A single *district* or deposit is studied in *all* its relations. *All* of the geologic problems which relate to it are successively studied; *all* geological principles are successively applied. The results make up a report which is distinctly a *geographic* unit of work. The method of special problems on

the other hand consists in the study of a single important *problem* in *many* districts and the grouping together of the observations thus collected in orderly arrangement so that some general law of mineral deposition may be deduced.

The extent to which the first or district method—valuable as it undoubtedly is—has dominated American geology is at once apparent on a survey of the literature.

Nearly all of the reports of the United States Geological Survey, from the days of Powell and King to the present time, have consisted of the description of single geographical areas, and in these later years with the increased attention which is given to ore deposits, this method of work has been increasingly prominent in the published reports of the Geological Survey.

In the reports of our state Geological Surveys the method has prevailed to an even greater degree and in some few of them finds its *reductio ad absurdum*. These are the state reports which are split up into volumes relating to the geology of very small areas of country—the county reports—in which each district is described with a wealth of detail and an interminable catalogue of cryptographic references to individual localities, property lines, fence corners, barns, corn cribs and hen coops on the farm of John Smith and John Doe, for the unravelling of which it would be difficult indeed to discover a key. Such reports may be serviceable to a few farmers and may help to enhance the popularity of local politicians, but as contributions to science or as a foundation on which the progress of modern geology is to be based, we cannot but ask, is their publication really worth while?

It is but fair to say that the report on the ore-deposits of New Mexico recently issued by the Federal Survey shows a departure from the old district method and as such it is to be most heartily commended, but it is but a single step in the right direction.

The value which a geological report may have seems to us to be dependent upon four things:

1. The utility of the work to the people who live in and operate the mines in the district discussed. This is an important element of value of the descriptive report and it is that which is chiefly

recognized by the residents of the region studied and unfortunately by their political representatives in our legislative assemblies.

2. The utility of descriptive work to mining engineers and professional men who travel from place to place and to whom a foreknowledge of the geological conditions in districts to be visited is imperative. This is probably the chief element of value of the descriptive report and it would indeed be difficult to overestimate the service which our Federal and State Surveys have rendered, and are still rendering in this respect.

3. The service rendered by the theoretical deductions made from the observed facts to our scientific knowledge of the general laws governing geologic occurrences of the kind described.

4. The availability of the general information to men who seek for information on some general problem or general law of geologic occurrence that they may apply it in their work.

It is in the fourth respect that our descriptive reports so lamentably fail. The man who seeks enlightenment on some one important general problem, such as secondary enrichment, or contact metamorphism, that he may apply the results of the work of others to the problems he may from time to time encounter, and which so often mean to him the future of a mine may find it in these descriptive reports it is true—but with what untold labor! A pile of ponderous volumes which reaches nearly to the ceiling and through which he must pick a painful and laborious itinerary to here and there glean some crumb of information that bears on his special problem, affords a task which may well seem formidable to the busy engineer with his many duties and his modicum of time. He is compelled to search in each report through page after page of information for which he has no need; pages which deal successively with geology, paleontology, stratigraphy, petrography, secondary enrichment, replacement, magmatic segregation, petrographic relations of the enclosing rocks, faulting, contact metamorphism; page upon page of mine descriptions, detailed citations of outcrops and descriptions of fossils; an immense mass of heterogeneous information bound into a single report—a report that is voluminous, exhaustive,

complete, but as many hued and kaleidoscopic as Joseph's coat.

It is for this reason that the valuable results which have been obtained with so much effort and expense are so often hopelessly buried, and require, in order to be rendered serviceable, a knowledge of the literature which most men do not possess. It is also for this reason that the great progress in economic geology which has been made in the last ten years has resulted in large part from those short general papers in which a single important problem is discussed, one problem studied and verified in its application to many districts—and not one district to which have been applied many problems. Posepny's general paper, Kemp's discussion of ore genesis, Weeds and Emmons and Ransome's discussion of secondary enrichment, Lindgren's discussion of contact-metamorphic deposits, and other such papers are in great measure the work which has given the impetus to the progress of economic geology. If they had not been written, it is doubtful if any but the very few would ever have known what secondary enrichment meant and that most valuable of results in recent economic geology would have remained forever buried in some great volume and there reposed as safe from intrusion as the bodies of the Pharaohs in the Pyramids of Egypt.

It is true, of course, that these papers are the result of the study of facts collected in many districts and that they would not have been written had not those districts been studied—but their appearance is none the less due to chance. An invitation is given to contribute a paper at some scientific meeting or an author is urged to contribute to some journal a paper of a general nature on some special problem and the facts thus observed are hastily correlated, usually after office hours, and a paper written which in the ordinary course of events would never have appeared. There is no settled policy either in the Federal Survey or any State Survey, nor in fact in many of our universities of directing attention to the study of some one definite problem of general importance or even of collecting together in a single bulletin all of the previously published information which bears upon some general problem.

It is not our purpose to decry the value of the descriptive method of geologic study. As a means for the careful collection of geologic facts it is indispensable and unless it is followed the facts upon which generalizations may be based cannot be collected, nor the papers which have so aided geologic progress written. What is more the great service for which our professional men express such appreciation could not have been rendered. But it is not the *only* method and it is our belief that its utility decreases as the geology of a country becomes more completely known and as the number of undescribed regions is reduced; that the facts collected do not lend science the usefulness they may if they are simply described and not interpreted in the light of similar occurrences elsewhere; that such interpretations are in themselves of small utility if buried in some descriptive work and not collected together with similar interpretations of genesis in other places; that the man who discusses a problem such as contact metamorphic effects, in a general paper can do so better if he has seen many such deposits than if he has seen two and relies for his knowledge of fifty others on descriptions of what he has not seen.

Why should we not add to the descriptive method the study of special problems? There are surely an abundance of them.

Here are a few that are today vexing our mining engineers and students of ore deposits:

1. The effect of climatic conditions on the superficial alteration of ore-deposits.

2. Are the metallic sulphides ever original constituents of igneous or sedimentary rocks?

3. What are the contact effects produced on different rocks by intrusive bodies of igneous rock?

4. How may normal types of ore deposits transformed into complex metamorphic derivatives be recognized?

5. What are the types of replacement and the criteria by which they may be recognized?

6. What is the effect of wall rock on the mineral content of fissure veins?

7. How may the association of igneous rocks with deposits of metallic ores be explained?

If one looks at some of the great works on geology he may see how successful the special problem method may be made. Scrope in his book on volcanoes, which even after so many years is still a classic, studied volcanoes in many places and finally collected together in one volume his observations on a vast number of localities. Would this book ever have been written if he had been occupied with the mapping and study of a great multitude of districts in one or two of which only there might have been active volcanoes? The descriptive method has its value but it has also its limitations. We do not urge its abandonment. To do that would without question be to give up one of the most useful fields of geologic work. We merely ask if it is not time that it be *supplemented* by the study of special problems? and that such study be inaugurated at least in some instances by our geologic corps that have both the men and the means to carry out these investigations?

Perhaps no better illustration could be found than the problem of secondary enrichment, one whose study has yielded, so far as it is yet developed, results of greater practical service than almost any other. At present we progress in our study of this subject by each man adding here and there a little of what he has observed in the few localities which he has had opportunity to study, and increase in our knowledge is very slow. If some able geologist were sent out to study this problem of secondary enrichment, now in Alaska, now in the tropics, now in a dry country and now in one of heavy rainfall, now in deposits of one metal, now in those of another, a vast array of clearly correlated geological observations could be gathered from which generalizations of incalculable value might be deduced, and deduced in a comparatively short time.

It should not be a difficult matter to assign such work to those who are members of our Federal Survey and other surveys. The greater number of mining districts have been studied and is it not more seemly that the time of those who have become skilled in detailed work should be devoted to these problems of

far-reaching importance than turned into the deadening labor of collating countless statistics of production? Is there not some danger that we may withhold from our national geologists opportunities for the most useful kind of work; that we may stifle the true genius of our great men by degrading brilliant investigators to the level of mechanical mappers and soulless statisticians?

It will be urged that the exclusively descriptive method is the result of a demand by the people of the country as expressed through our legislatures and Congress, that if other methods be added to it money for the prosecution of research may not be forthcoming. Such arguments show an unfortunate willingness to accept the judgment of men not engaged in scientific work. Simply because the men who compose our legislative bodies do not profess a knowledge of geology, are we to make no effort to show them the true needs of the situation?

Does the failure to adopt new methods lie at the door of our legislators? We think not. Rather is it the result of the too successful development of the purely descriptive method. Our geological corps have become so occupied with a kind of work which has already proved effective that the opportunity for new and fully as important methods bids fair to pass them by unheeded.

J. D. IRVING.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

CRITERIA OF DOWNWARD SULPHIDE ENRICHMENT.

DISCUSSION OF PAPER BY F. L. RANSOME.

Sir: Mr. Ransome's interesting paper on the "Criteria of Downward Sulphide Enrichment" is a valuable statement of the indications of descending enrichment, and will, we may trust, lead to the establishment of precise rules which the miner may apply to various types of ores and mining fields. Mr. Ransome's paper shows the difficulty or perhaps at present the impossibility of finding any one universally applicable criterion which may be applied to any new mining field. The two general criteria—variations of ores related to the topography, and the occurrence of leached gossan over rich sulphides passing down to poorer sulphides—may no doubt be trusted anywhere; but such evidence is only obtained after extensive mining. Though helpful in regard to the later mines on a field, they rather explain to the miner the facts that he has already learned than help during the opening of a field, the time at which the miner is most ready to turn to the geologist for guidance.

One criterion which is sometimes available in developed mines is derived from the distribution of shoots and nuggets. If ore shoots give off branches which continue upward, tapering out above, the probability is that the lode was formed by ascending

solutions. If on the other hand, successive branch shoots point downward they have probably been formed by descending solutions. There may be occasional exceptions due to the structure of the country rocks, branches going upward and downward along weak or permeable planes; but even then the detailed structure will usually show the direction the solutions tend to take. Indications from the distribution of ore shoots and nuggetty patches can be especially recognized in mines in ancient stratified rocks, as in the typical goldfields of Australia. For example, in Bendigo, though the gold quartz veins are thickest upon the crowns of the arch, the ore is usually richest on the thin lower ends of the saddle shaped folds of quartz. The quartz saddle has no doubt been formed by ascending solutions; but the gold in such cases has been concentrated in the thin lower ends of the saddle by secondary redeposition. Similar evidence occurs at Ballarat, and I have referred to some cases in a Report on the Ballarat East Goldfield. Here, as in other goldfields in Victoria, there is a tendency for the gold to occur in nuggets and nuggetty patches in depressions on the foot wall, where the lode rests on an impermeable bed. Cases occur where the gold has been collected into a nugget at a point where water percolating along the top of a band of slate has been checked by a ledge or step due to a small fault. In all these cases the gold is associated with iron sulphides and I can see no chemical evidence below the zone of oxidation which will distinguish the secondary from the primary deposition. There are the usual indications of secondary enrichment near the outcrop of the lode and speaking generally there is a steady fall in the yield of the ore from the surface downward; but even at considerable depths there is evidence of secondary changes during which the movement of the gold has been downward.

Among the mineralogical criteria Mr. Ransome calls attention to the evidence of kaolinite and he remarks (pp. 209 and 212) that kaolin is recognized only in the zone of sulphide enrichment and in the oxidized zone. On page 212 he remarks that the association of kaolinite is a most useful criterion for downward sulphide enrichment. I presume by kaolin Mr. Ransome means

kaolinite, as he refers to that species on page 212; and he suggests that kaolinite, even where it has been attributed to a hydrothermal origin, may have been formed from sericite by acid solutions descending from an overlying zone of oxidation. The evidence of kaolinite, both on the mainland of Europe and in England, shows that kaolinite itself is not due to descending acids. The china clay masses of many European localities and in Cornwall and Devon offer strong evidence of having been formed by ascending acids, notably boric and fluoric acids. The essential constituent of the china clay masses of Cornwall is kaolinite, and both its paragenesis and field relations support its deep-seated hydrothermal origin. Thus it is associated with abundant tourmaline and topaz and occasionally fluorite, which is however rare, owing to the usual poverty of lime. The quartz grains found in the china clay masses have often been etched and altered into berry-shaped bodies, owing to the attack of the acids. Mineral species typical of descending waters are conspicuous by their absence. The field relations of the china clay masses also show their formation from ascending acids, and it has been authoritatively stated, both from the English and German localities, that not one case is yet known in which the bottom of a china clay mass has been found. China clays, on the other hand, pass upward into a partially altered, and that in turn into comparatively unaltered granite. From the big china clay masses tongues may be seen passing upward into granite; these may finally taper out into a thin vein of schorl, probably bounded on either side by an inch or two of china clay.

It may be said that the kaolinite at Amlwch in Anglesea, the classical English locality, may be of a different origin, for it occurred there in a mineral vein; but the mine is now inaccessible and there appears to be no very definite evidence as to how the kaolinite occurred. Kaolinite has also been found in veins in Scotland; but so far as I know the evidence, it favors the origin of the mineral by hydrothermal rather than by descending meteoric waters. Mr. Ransome is probably referring to kaolinite associated with sulphides, and it may be said that the china clay stocks are not relevant; but as kaolinite is an intractable

material, it may easily be impregnated with sulphides and it is important to remember that many geologists now reject kaolinite as a proof of descending action.

J. W. GREGORY.

Sir: I cannot concur in Mr. A. N. Winchell's[1] statement that chalcocite in the Butte veins is "largely, if not wholly secondary." Secondary chalcocite as a product of descending surface waters is present in large amounts in the Butte veins forming wonderfully rich ore bodies; in fact, there exists in Butte, as in Bingham, Ely and other disseminated chalcocite deposits, a "chalcocitization zone," or zone of "sooty chalcocite," which is limited in vertical extent to depths from 50 to 800 feet below the lower limit of the oxidized zone. I am strongly of the opinion that the greater part of the chalcocite of the Butte deposits which appears as the gray massive variety, is of primary origin, primary in the sense that it was deposited from deep-seated ascending solutions, and secondary only in that it was one of the latest minerals to form near the close of a comparatively long period of intense vein-forming activity.

As Mr. Winchell stated, enargite is undoubtedly a primary mineral, but it is probably of slightly younger age than the earliest formed quartz and pyrite. In some instances enargite is also secondary and forms a product of descending surface water enrichment. In many rich copper veins of the Butte district, especially in the Berkeley mine, solid enargite ore extends to the oxidized material, with no marked development of chalcocite, neither immediately below the oxidized zone nor at greater depths. While enargite is a valuable source of copper at great depths, the same is true also of the higher levels. I have often seen widths of from two to fifteen feet of enargite reaching to the oxidized zone, where the line of demarkation between the sulphide and oxidized ore was extremely sharp and clear cut. As a general statement, it cannot be said that enargite is on the increase as greater depths are reached, although it is undeniably true that it is a wonderfully persistent mineral with depth, but

[1] A. N. Winchell, ECON. GEOL., Vol. 5, 1908, p. 488.

no more so than chalcocite which has proved to be more abundant than enargite as a source of copper in the deepest levels of the High Ore mine.

Bornite occurs widely distributed both as a primary and secondary mineral. It results from the alteration of either pyrite, chalcocite or enargite and is often seen to be a transition product between pyrite and chalcocite; also in the reverse reaction where chalcocite passes by gradual alteration stages through bornite to chalcopyrite. While bornite is commonly an alteration product, and therefore secondary, it probably does not often result from the action of downward moving surface waters, but is generally a product of ascending solutions.

In the Butte copper veins, the alteration processes affecting the copper minerals have not always been processes of enrichment, but often quite the contrary. The alteration of massive chalcocite to bornite is common, as is the change from enargite to chalcopyrite, and covellite to chalcopyrite Covellite, however, is of limited distribution areally, but in vertical arrangement it has been found from the upper levels to depths of 1,600 feet, in which latter case, it is found intimately associated with enargite, chalcocite, quartz and pyrite.

Mr. Ransome's statement that chalcocite is always a product of downward sulphide enrichment seems rather broad and sweeping in effect. I believe that the "sooty chalcocite" of the disseminated chalcocite deposits has been deposited from descending sulphate waters, but I am of the opinion that much of the massive chalcocite of Butte and possibly many other localities, has been deposited from ascending waters.

RENO H. SALES.

BUTTE, MONTANA,
September 1, 1910.

CONTROLLING FACTORS OF ORE LOCALIZATION IN THE OZARK REGION.

The usual attempts to account for the localization of the ore deposits of the Ozark region have been mainly theoretical in character. Recently data exact enough for quantitative determinations have been made available.

Although in an uncertain way mining men have been able to open up important ore-bearing areas and to set off productive tracts from broader strips of poor country, they have not as yet devised any practical working scheme which can be depended upon to predict the occurrence of new ore-bodies. The nearest approach to any definite rule is the connecting of the ore deposits with lines of present stream-ways. In some cases there manifestly is good reason for such association. Thus far, also, all attempts of the scientists to arrange the principal ore-bodies along such structural lines as faults have proved, except in isolated instances, quite as unsuccessful. Nevertheless, all who have worked in the region have been deeply impressed with the notion that in some way or other there must be some intimate dependence of ore occurrence upon geologic structure.

Notable faulting is not characteristic of the Ozark region. The majority of the profound faults alleged to occur in connection with the ore-bodies have proved to be, upon more critical examination, stratigraphic disparities produced by ancient waterways along the horizons of old erosion surfaces. The most remarkable of such unconformity-levels within the limits of the region is that known to exist at the base of the Coal Measures. The joint-systems when they will have been eventually made out, will be found, no doubt, to be largely instrumental in initially determining the courses of underground-water currents and channels.

When in charge of the Missouri Geological Survey, so long ago as 1895, I recognized and carefully located, in various mining camps, a number of shallow synclines and underground erosion-troughs. With them were associated the principal ore-belts. At the time no opportunity was offered to publish the details

of the discovery in the reports of the survey, although several allusions were made to them at different times. From a knowledge of these relationships several of the most important ore-bodies thus located with reference to the local geologic structure were afterwards opened up.

In the main, the ore deposits of the Ozark region may be regarded as occurring in more or less well-defined basins or troughs. From a practical standpoint the recognition of this principle has a far-reaching significance. It matters little what is the geologic origin of these ore-accumulating depressions; for they are produced in different ways. They may be true synclines, or structural troughs, as predominate in the central Missouri mining district. They may be occasioned by local faulting, as in some parts of the northern Arkansas district. They may be inequalities in ancient erosion surfaces, as in the southeast Missouri district. They may be due to both flexing and warping of strata, as in the southwestern Missouri district. Or they may be produced by the caving in of underground channels, or caverns, and a consequent damming of the outlet, as in many instances in the last mentioned district. Detailed descriptions of the several districts are found in another place and need not be referred to farther here.

As presented in geologic cross-section any sagging of strata constitutes a syncline. Flexing of this kind is usually, without further discrimination, ascribed to mechanical deformation of the class to which mountain-building belongs. This is, however, not always strictly true. Geometrically, the phenomenon is considered only in two dimensions. It is really a problem of three dimensions. As such the form considered is best regarded not as a simple syncline, nor even an irregular trough, but as a basin. So far as ores are concerned synclines may be treated broadly as basins; and their origin not restricted alone to those structures which are formed when rock-masses have undergone intense lateral compression.

In their broader relationships, minor "synclines," or basins, may be regarded as formed (1) through original unevenness of the sea-bottom, (2) through irregularity in deposition of the sedi-

ments, (3) through flexing of strata on account of orogenic movement, (4) through bending of rock-layers during the process of fault-movements, (5) through the settling of strata on account of local changes in volume of terranes below, (6) through local intrusions of igneous masses, and (7) through general tilting of already uneven strata, as along unconformity-planes.

The general association of the workable ore deposits of the Ozark region with basins is far more significant than at first glance might appear. It seems to make small difference what is the immediate origin of the basins. The principal point to be kept in mind is that the introduction of the structures mentioned gives rise to an impounding of the underground-waters and a production, on new lines, of all the conditions of a permanent ground-water level. Sulphatic waters passing into and through such subterranean ponds deposit some of their metallic loads as sulphides, just as they do in the enrichment zone of normal fissure-veins. How the precipitation is brought about is immaterial. It may take place through the mingling of different currents, by the presence of organic matter, by the association of carbonaceous material, or in the presence of decomposing sulphides. In this zone and under impounding conditions there are invariably present an abundance of adequate reducing agents.

In the southeast Missouri Lead district the localization of the ore-bodies appears to be influenced chiefly by the character of the pre-Cambrian troughs corraded out of the still older granites. The Central Missouri mining district presents true structural troughs, or synclines, as the prevailing feature, although subterranean channel-ways now filled with sands and bituminous clays have occasioned minor ore-bodies. Both synclines and faults have produced basin conditions in the northern Arkansas district. In the upper Mississippi district synclines alone are determining factors.

Conditions are complex in the southwestern Missouri zinc district. That they appear more complicated in this area than in the other districts may be due partly to the fact that the district

has received more detailed study than any of the other fields. The great Springfield-Joplin syncline pitching westward down the slope of the Ozark dome clearly explains many of the former puzzling features connected with the distribution of the ore-bodies. The cross-arches long known to exist in the vicinities of Galena, Joplin, Webb City, Carthage and other places are believed to be of first importance. Close-patterned warping of the strata has been suspected ever since the detailed, large-scale, topographic maps of the Carthage, Joplin and other neighboring quadrangles were first constructed by the Missouri Geological Survey more than a decade and a half ago. Although not so accurate as it might be, yet still presenting the broader features, the lately published folio 148 by the Federal Survey showing the underground contours of the Grand Falls Chert surface displays in a remarkable manner the relations of the ore-bodies and the basins.

In the Joplin district the profile of the Grand Falls chert, along a line passing through the principal mining camps brings out several important features bearing directly upon the question under discussion. By reference to the figure below the principal ore-bodies are noted to be located in the troughs or sags due in part to the close-patterned warping and in part to definite parallel flexing. The ridges of Galena, Joplin, Webb City and Carthage are true anticlines trending nearly northwest. They are the cross-bars of the Springfield-Joplin syncline which pitches nearly due west. The ore-bodies are thus seen to have definite relationships with the geologic structure. It seems very probable that the retreating margin of the impervious Coal Measures has had a very important influence in impounding the underground-waters by raising the local ground-water level. There are strong reasons for believing that this has been the immediate cause of the localization of many of the principal ore-bodies of the district. Since the inclination of the ground-water surface is not so great as that of the strata there would be raised at once at the point where the groundwater level intersected the base of the Coal Measures a formidable barrier, or dam, which would impose extensive impounding conditions at

the lower end of the great syncline. Joplin appears to be located in just such an area.

Ore-bodies in large solution cavities, particularly along the major lines of jointing, and in dammed subterranean waterways are also of common occurrence in the Joplin district. Corrasion channels in the plane of unconformity at the base of the Coal Measures or stream-ways formed before the deposition of the Des Moines shales do not at present writing appear to exist. So far as personally known the débris sandstones and shales usually found in this connection are not depositions of Carboniferous times at all. All appear to be fillings of very recent underground channelways that either caved in or filled up without their roofs giving way. As such there must be seldom any real relationship between the pre-Coal Measures drainage-lines and the ore-bodies.

The Ozark region is one in which some of the structural features mentioned are not at first glance easily determined. The general dips of the strata are so small, the flexing so slight, the warping so close-patterned and gentle, that it has been only through the application of recent and refined methods of investigation that the actual proofs of some of the former deductions were secured. Something of the delicacy of the standard of measurement may be judged when it is stated that a warping or flexing of less than a dozen feet may give rise to basins containing the largest of ore-bodies. The principles involved are, perhaps, best considered by referring first to examples of other districts where with the same vertical values the lateral components are infinitely smaller and the angles much higher. Reference is made especially to the ore deposits of Lake Valley and Magdalena, New Mexico.

In the central Missouri mining district the series of parallel synclines gives conditions like those of Joplin with the Coal Measures margin not far away. All of the ore-bodies appear to be confined strictly to the bottoms of distinct structural troughs. With this conception of the geologic conditions systematic prospecting should make this a very much more important mining district than it now is.

In the southeastern Lead district the general conditions are also like those in the southwestern area. Corresponding to the warped surface at Joplin is the uneven erosion surface of the unconformity-plane at the base of the Cambrian section. Instead of porous zones composed of brecciated cherts and limestones are the layers of porous dolomites. The ores are "disseminated" through particular beds instead of being formed in brecciated zones, or into "runs" along underground channels filled with débris.

The Ozark ores are mainly strictly vadose deposits. As such they have no connection with deep-seated activities. They are localized in definite basin-like depressions of diverse origins. The immediate conditions influencing local precipitation of circulating ore materials are those of total or partial impoundment of the underground waters usually near the retreating Coal Measures margin. The most important of the controling factors of ore-deposition is geologic structure, producing basin conditions.

C. R. KEYES.

REVIEWS

The Iron Ore Resources of the World, An inquiry made upon the initiative of the executive committee of the XI International Geological Congress, Stockholm, 1910, with the assistance of geological surveys and mining geologists of different countries. Edited by the general secretary of the congress. Two volumes, 4to, lxxix + 1,068 pages with 22 plates and 142 illustrations in the text and accompanied by an atlas of 43 maps. Stockholm, Generalstabens Litografiska Anstalt. Price, two volumes and atlas, £3.

This work is the result of a circular sent by Hj. Lundbohm, Hj. Sjögren and Walfr. Petersson, representatives for mining geology in the Swedish Executive Committee, to geological institutes and individual geologists the world over asking for information regarding iron ore.

In many countries an official was detailed by the national geological survey to prepare the report for that particular country. Altogether some fifty writers were concerned in the preparation of the work. The names appearing in this connection are, for the more important countries at least, those of well-known technical writers. These should insure for the work a reliability which will commend itself to critical readers. While there are some inaccuracies and omissions, these defects could hardly have been remedied without a much more extensive inquiry than was possible under the circumstances.

Apparently it was intended to publish the work with the resources at the command of the committee, but the material became so voluminous that the coöperation of a publisher was sought. The languages employed are French, German or English, but English predominates. While some of the maps have Russian legends, in most cases the legends are given in one of the languages generally understood by scientific men. The limitation of the choice of languages to these three very materially increases the value of the work to many readers and gives them access to material which heretofore was not available; but this restriction doubtless hampered a few writers and probably accounts for some of the errors of orthography and typography.

The keynote of this work is quantitative estimates. The preface cites as a precedent a publication by the British government entitled, "Reports on Iron Ore Deposits in Foreign Countries." There is also mentioned the report of the National Conservation Commission of the United

States. Attention is called to President Roosevelt's plan for a Hague conference to consider the establishment of an inventory of the world's natural resources and this work is offered, "as an accomplished solution of one of the special missions incumbent on the conference." Three groups of ores are established, "in group A should be included such cases in which a reliable calculation of the extent of the deposit, based on actual investigations, has been carried out; group B should include such deposits in which only a very approximate estimate can be arrived at; and group C should contain such deposits as cannot be represented in figures at all." Supplementary information is asked regarding materials with low percentages of iron or considerable quantities of titanic acid. Considering continents and archipelagos and leaving the polar regions out of the consideration, it is shown that of the total land surface, Group A includes 13.3 per cent., Group B 10.3 per cent., Group C 51.6 per cent, and that 24.8 per cent. are not accessible for the present inquiry.

The United States, most of Europe and Japan are classed in Group A. Group B includes Newfoundland, Cuba, Mexico, Brazil, certain small states of southern Europe and northern Africa, Corea, southeastern Australia and New Zealand. Group C includes Canada, Central America, much of South America, most of Asia and of Australia and in Africa, the valleys of the Nile and Congo, with other scattered areas. Regions not embraced in the inquiry include Alaska, various islands in the Arctic and elsewhere, equatorial Africa, Arabia, plateaus of south-central Asia, Indo-China and scattered areas in Asia, Africa and South America. In maps B and C quantitative expression is given to the actual supplies in the United States, Newfoundland, Cuba and eastern Europe. Potential supplies are indicated in the same areas and at few other places in the world. Potential supplies, very vaguely determined, are indicated also for parts of Africa. The remaining maps cover individual countries, regions or mines.

The 1,068 pages by the various authors which are the direct result of the request are partly the expression of personal knowledge but are probably more largely compilations. This compilation, in consequence of its mode of preparation, is far more reliable than most treatises on the world's ores of some particular metal. In some instances important information is for the first time made public.

A perusal of these pages shows how faithfully the various writers have endeavored to comply with the instructions regarding quantitative estimates. In some cases data already compiled served as the basis for the estimate. In others estimates as accurate as possible were made from such information as was available. Confessedly, this work represents, "the present knowledge of iron ore resources," rather than the

subject expressed in the title. The division into three groups simplifies the problem. In some cases further subdivision has been made, for instance, into actual, probable and possible ore. Probably the most careful and detailed estimates have been made in Sweden. Here, although some of the ores are contained in many small deposits, estimates have been made for part of the ores on the twofold bases of richness and phosphorus contents, giving six classes.

The request for information called not only for the quantity of iron ore (expressed in metric tons) and its distribution but also for its richness, controlling impurities and other factors, determinative of its technical utilization. Aside from the specific requests the various writers were given freedom regarding the remainder of the production. Rather uniformly they availed themselves of this latitude to describe the geological relations of the ores. Where information was available these descriptions are satisfactory although brief. The work is accordingly valuable not only from the industrial standpoint but as an interesting handbook on the geology of iron ore. Indeed to the geologist its chief value will lie in this feature. The well-known types of iron ores are shown to be nearly world wide. Not so well known are the laterite ores, those aluminous ores, sometimes bauxitic, which are now known to be widely distributed in tropical regions. These ores are variously regarded as valuable or as worthless. They resemble the bog ores of the northern regions, but, while like them in being superficial, they apparently have greater depths and cover vast areas. They are low grade but not lower than bog ores which have been worked in earlier periods of our iron history. Probably the one question which the title of this work will most abundantly provoke will be regarding the possibility of any region rivalling that of Lake Superior. This question this publication does not attempt to answer. It shows this region to be the leader in actual and potential reserves. On the other hand the volume does show that banded jaspers in ancient crystalline rocks are known in South America, Africa and India, and that these carry in places very large bodies of iron ore.

In the description of the iron ores of the United States it is stated in regard to the Oriskany ore that, "the sandstone carries sufficient iron to have yielded the metal," implying that the sandstone was the source of the ore. This is incorrect. As a matter of fact, the Oriskany sandstone does not carry enough iron to have yielded the metal. As an hypothesis this is new to the reviewer and is open to serious question inasmuch as the sandstone is thinner than the ore bodies. Attention is called to the gray hematites of Alabama which have been exploited chiefly on paper, but no mention is made of similar ores in Virginia which have been mined for a quarter of a century and which constitute

a bedded deposit that outcrops continuously for 20 miles and with a thickness of 6 feet for long distances.

In addition to the 1,068 pages of reports on the various countries there is a 56-page summary by Professor Sjögren which includes a brief digest of each country and an 8-page general résumé. In this summary the surprising comparison is made that the iron ore of Newfoundland, which is largely submarine but is regarded as actual reserves, exceeds in quantity the figures given for the Lake Superior region. The figures for the Lake Superior region of 3,500 million tons actual and 72,000 million tons potential reserve are for ore over 50 per cent. Sjögren says that the figures for this region for material above 35 per cent., namely 276,250 million tons, might also readily be put down as potential reserves. He shows further that of the known 60 per cent. or better ore there is a total of 1,300 million tons, of which four fifths is in northern Sweden.

He gives the following final world's summary:

	Actual Reserves.		Potential Reserves.	
	Ore MT.	Iron MT.	Ore MT.	Iron MT.
Europe.....	12,032	4,733	41,029	12,085 + considerable
America.....	9,855	5,154	81,822	40,731 + enormous
Australia.....	136	74	69	37 + considerable
Asia.....	260	156	457	283 + enormous
Africa.....	125	75	Many thousands	Many thousands + enormous
Total.....	22,408	10,192	> 123,377	> 53,136 + enormous

By considering metric tons of metallic iron per square kilometer, which is called the iron quotient, a basis of comparison of the several countries may be obtained and the curve of the quantities of the best developed countries projected to the less known quarters. The following table was compiled from Sjögren's figures.

METALLIC IRON PER SQUARE KILOMETER (IRON QUOTIENT).

		Actual.	Potential.
World	Group A	404	2,838
	Group B	225	261
Europe		488	1,243
North and South America		135	1,063
United States		293	4,741
Australia		9	4
Asia		4	6
Africa		3	

On the assumption that the entire surface of the continents ought to show the same iron quotient that the better known parts do, there is obtained a total of actual and potential supply of iron for the world of 424,487 million tons, or about six times the known supplies.

On the basis of the figures of actual known reserves and the present rate of consumption, there is a supply of iron ore for less than two centuries. If the increasing rate of consumption be taken into account, there is a supply for sixty years. If the projected total supply of actual and potential resources are all included in the estimate, the time when these shall be exhausted becomes relegated to the very distant future.

R. J. HOLDEN.

SCIENTIFIC NOTES AND NEWS[1]

THE INTERNATIONAL GEOLOGICAL CONGRESS.

During the week from the eighteenth to the twenty-fifth of August the Eleventh Session of the International Geological Congress convened in Stockholm, Sweden.

The congress was attended by nearly seven hundred geologists and mining engineers from all the countries of the world and was one of the most productive of valuable papers as well as one of the most enjoyable that has yet been held.

The Swedish geologists and the Swedish government vied with each other in the lavishness of the entertainment of their guests, in the efforts which they made to place in the hands of the visitors complete geological treatises on the geology and economic resources of the country, in the facilities for comfort and convenience which they provided and in the labor which they expended in planning both the excursions and the business sessions of the convention.

The sessions of the congress were held in the House of Parliament, the University of Stockholm, the House of Lords, the Conservatory of Music and the Järnkontor, the papers dealing with related subjects being usually read in a single locality. Luxurious reading and writing rooms were provided in the House of Parliament, comfortable and commodious rooms were reserved at all of the best hotels in the city and arrangements were made with restaurants for the accommodation and convenience of the members, and an unusually efficient and active information bureau maintained.

On August 18 the members were welcomed for the Swedish government by the Crown Prince, and the congress then declared opened by the king. The business sessions and sessions for the reading of papers were then held.

The papers read were divided into five groups, each one of which comprised all related papers which were read at special sessions in places set apart for them. The groups were as follows: (1) The geology of the pre-Cambrian systems, (2) the changes of climate after the maximum of the last glaciation, (3) the iron resources of the world, (4) the geology of the Polar regions, (5) the sudden appearance of the Cambrian fauna.

The literature placed at the disposal of the members of the congress through the efforts of the Swedish geologists was voluminous and more than usually valuable. It consisted of: (I.) A volume on the iron ore resources of the world (elsewhere reviewed in this journal); a large volume with an accompanying atlas that is one of the most valuable publications that has yet been issued by any congress and one which gives in great detail nearly all that there is of our present knowledge on the world's supply of iron; (II.) a volume on the climate of past geologic ages, and (III.) papers describing the regions visited on the various excursions in two large volumes, covering in great detail nearly all of the important geologic features and ore deposits of Sweden. Besides this, maps of Stockholm, city handbooks and innumerable smaller pamphlets that added much to comfort and convenience had been prepared at great labor and expense.

The papers read at the congress which are of chief interest to economic geologists were:

August 18.

Ch. R. van Hise: "The Influence of Applied Geology and the Mining Industry upon the Economic Development of the World."

August 19.

F. R. Tegengren: "General View of the Exhibition of Mine Maps."

Walfr. Petersson: "Die magnetometrischen Untersuchungsmetoden."

V. Carlheim-Gyllensköld: "The Magnetic Survey of the Kiirunavaara Iron Ore Field."

August 22.

J. Keidel: "Die neueren Ergebnisse der geologischen Untersuchungen in Argentinien."

H. G. Ferguson: "Gold Deposits of the Philippine Islands."

Hj. Sjögren: "The Geological Age of the Different Ore Types of the Scandinavian Peninsula."

P. Krusch: "Die Lagerstätten von radioaktiven Mineralien und die Radiumproduktionsbedingungen."

M. Lyon: "Les formations aurifères en France."

Excursions were held before, during, and after the congress beginning on the twenty-fifth of July and closing on the thirteenth of September. These excursions included visits to Spitzbergen, to all parts of Sweden, including all of the more important mines, regions of geologic, physiographic and palæontologic interest and to a great number of localities of historic interest. It would be impossible in so small a space as is here available to give the detail of these excursions and to recite the pleasure and profit which the members of the congress derived from them—suffice to say that for excellence in the judgment which governed their selection, executive management of detail, comfort and luxury of travel, lavishness of entertainment and cordiality of welcome, they have set a precedent which it will be extremely difficult, if not impossible, for any other country to rival.

MR. JOSEPH A. HOLMES, formerly of the United States Geological Survey has been appointed Director of the Bureau of Mines by President Taft.

THE Thirteenth Annual Session of the American Mining Congress was held in Los Angeles, Cal., from September 26 to October 1 inclusive. The meeting was a large one, as more than 1,200 members and delegates had registered. Among those present were Joseph A. Holmes, D. W. Brunton, J. Parke Channing and Gifford Pinchot.

Probably the most important and significant paper was that read by Mr. E. W. Parker on September 29 concerning "Conservation as it Affects Coal Lands."

MR. WALDEMAR LINDGREN, of the United States Geological Survey, who attended the Geological Congress in Stockholm, arrived in Washington on September 28. He will shortly go west in the interests of the survey.

C. H. SHAMEL, of Seattle, Wash. sailed on October 11 from San Francisco, for the Phillipine Islands. He will spend perhaps four months investigating the mining, geological and agricultural features of these islands. Afterwards, he will spend some time with friends in China and make brief stops at the Malay Peninsula, Ceylon and Hindustan, returning by the way of Europe. He will return to Seattle in the fall of 1911, and resume his practice of law and his work in the Law Department of the University of Washington. While in the Philippines, his address will be in care of Elk's Club, Manila, P. I.

DR. MONCRIEFF FINLAYSON, of the Royal School of Mines, So. Kensington, London, S. W., has gone to the Burma Oilfields to carry out two years' exploration and surveying on the staff of Steel Bros. & Co., of London.

GEORGE F. KAY, professor of petrology and economic geology, University of Iowa, spent about six weeks of the months of July and August examining coal claims in the Katalla field, Alaska. He was in the employ of the Forest Service, of the Department of Agriculture.

RECENT appointments in the School of Mines of the University of Pittsburgh are as follows: Horatio C. Ray, B.S., instructor in metallurgy; Harry N. Eaton, A.M., instructor in geology and petrography; Henry Leighton, A.B., instructor in mining geology and mineralogy; Harry B. Meller, E.M., instructor in mining.

THE Toronto correspondent of the New York *Evening Post* states that appointments at the university have been made as follows: H. E. T. Haultain, professor of the new chair of mining engineering; Alex. McLean, lecturer in geology.

EDWARD W. BERRY, associate in paleobotany at the Johns Hopkins University, has recently been appointed a geologist on

the U. S. Geological Survey and will spend the fall in paleobotanical collecting in the south. Special attention will be devoted to the Tertiary with a view to securing data for correlation. The area covered will extend from Florida to Arkansas.

PROMOTIONS at the Johns Hopkins University have been made as follows: Charles K. Swartz, Ph.D., collegiate professor of geology.

A SERIES of lectures on the conservation movement by several of the government experts is in progress this summer at the University of Chicago, forming part of the program of public lectures which, according to custom, are open to all who care to attend. The subjects of the addresses thus far announced are "Conservation of Mineral Resources," "Reclamation of Waste Lands" and "Conservation of Forests." Among the speakers announced are: Charles W. Hayes, chief geologist of the United States Geological Survey; Frederick H. Newell, director of the Reclamation Service, and Chief Forester Henry S. Graves.

PROFESSOR F. R. INGALSBE, of Lehigh University, has spent the past summer in making a complete magnetic and geologic survey of the property of the Cheever Iron Ore Company at Port Henry, New York.

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